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Evolution by Atrophy.

By W. P. PYCRAFT.

IN our study of evolution by atrophy, illustrated by the wing of the bird, we have so far considered only cases of continuous retrogression, ending in the absolute suppression of the wing, and the consequent evolution of a flightless bird; an evolution be it noted of a very unmistakable kind, for the loss of the wing has been in many of these cases accompanied by an enormous increase of stature, and the development of ornamental plumage of a very striking character, as is seen, for example, in the ostrich and cassowary. This matter of ornament, however, and one or two other points more or less remotely associated therewith, we propose to discuss on a future occasion. The aim of this chapter is to bring out another aspect of this theme of evolution and devolution in birds—to wit, the development and retrogression of the wing.

As we have already remarked, the retrogressive phases of the wing begin with a shortening of the remiges, especially of the outermost primaries. Now this shortening, it is significant to remark, seems always to be associated with a corresponding degree of degeneration in the rest of the contour feathers of the body, which seems to indicate that the well-being of one set of feathers affects all the rest; as if, to put it another way, the determinants in the germ-plasm destined to form feathers were all affected, in greater or less degree, by the standard of perfection attained by the primaries, or at any rate by the remiges. Exceptions to this rule will, of course, be met with, but taking the evidence as a whole it will be found that a loose, "discontinuous" type of plumage, recalling that of the ostrich tribe, will generally be found associated with feeble powers of flight, and this state of things is most marked in birds which have become absolutely flightless, as in the ostrich tribe.

The wing of the great auk, it may be remembered, seems to present a phase in the evolution of the fin-like anterior limbs of the penguins. And here we have a helpful solution of the problem so often put to us—What can be the selection-value of initial steps? In the evolution of the penguin paddle there are no "initial steps" in the sense usually meant by those who raise this question. In proportion as the wing lost its power of sustaining the body in the air, so it increased its efficiency as a paddle, and in proportion with this increase so it assumed its paddle-shape. The evolution of the paddle of the turtle can similarly be traced from an ambulatorial limb. And in like fashion we may safely assume that th re were no "initial steps" in the evolution of the typical wing; that is to say, there was no "incipient wing," useless as an organ of locomotion in any capacity, as some seem to assume; there was no long period of incubation during which the bird was unable to use the fore-limbs, in any way, until, by "minimal increments,"

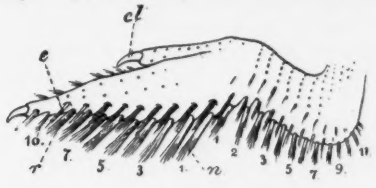

FIG. 1.

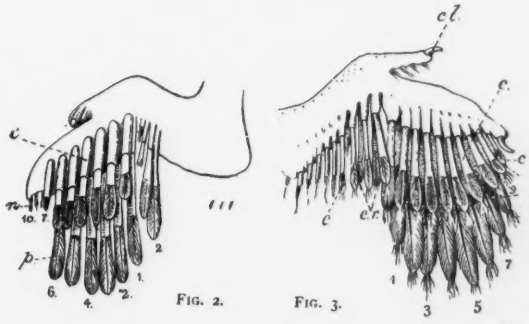

FIG. 2. FIG. 3.

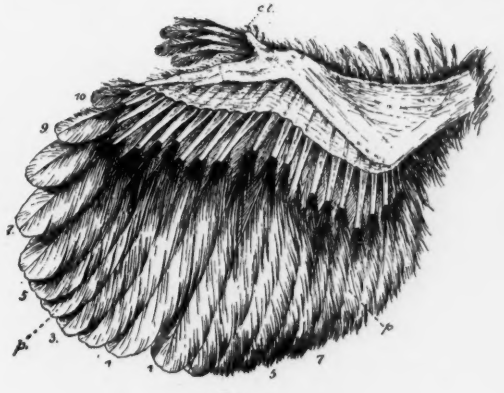

FIG. 4.

Wings as Organs of Prehension. (After Pycraft.)

Fig. 1.—Left wing of nestling Hoatzin, showing the long pollex and index finger and the large claws.
Fig. 2.—Wing of a nestling of the Common Fowl, showing vestiges of the climbing wing in the arrested development, of the outer primaries.
Fig. 3.—A later stage in the growth of the same wing, showing the fan-shaped form of the primaries.
Fig. 4.—Wing of a nestling Touraco, which has just emerged from the climbing stage.

the "wing" came into being. This wing, as time will prove, was evolved by a process of gradual change of function, a process which the writer indicated in these pages some three years ago.

But, happily, certain embryological and post-em-

bryological stages help us to a more secure position in regard to this matter, and show, moreover, how the work of evolution and devolution may go on in one and the same organ. In the early stages of the developing chick, the manus takes the form of a "paw" rather than of a wing, and moreover shows traces of a fourth digit, and more numerous carpals than appear in the adult. Therein we have a reminiscence of the time when the wing served the purpose of a foot. But this stage speedily gives way to that of an indubitable wing, albeit differing markedly, perhaps, in the proportions of its several segments from that of the adult wing, and further presenting more or less well-developed claws on the terminal phalanges of digits I. and II., and, in the case of the ostrich, of digit III. These claws were formerly supposed to be merely vestiges of a reptilian ancestry. As a matter of fact it would seem they are something more than this; they have been, as it were, carried over from these reptilian days, and this because they served a useful purpose, though in many groups of birds they have disappeared, having become functionless throughout all stages of development; though in others they remain with a dogged persistence throughout life, as in the ostrich tribe, wherein they can serve no useful purpose during any stage in the life-history. But we are anticipating. Let us take a rapid survey of the wing from its earliest beginnings, so far as it can be traced—to the wing of Archæopteryx, in short. This, in spite of the statement constantly met with in text-books, differed from the wing of modern birds only in degree and not in kind. And these points of difference are confined to the carpus and manus. The former was made up of two free proximal carpals, as in modern birds, and of a persistent semi-lunar mass of distal carpals, exactly resembling those of, say, a young fowl, before fusion with the metacarpals; the metacarpal of the pollex, similarly, remained as in the fowl at this stage. It is probable that stage represented the adult condition in Archæopteryx. The metacarpals differed chiefly in that Mc. III. was straighter than in modern birds, while the digits differed therefrom in that the index and medius fingers were of considerable length; the former produced beyond the quills to form a free finger tip, and the latter beyond the posterior patagial membrane. All terminated in a large claw; in existing birds a claw on the medius or digit III. is met with only in the embryonic stages of *Struthio*, and then but rarely.

Whether these claws served any purpose during adult life is open to question; they may, of course, have served to convert the hand into a climbing organ during the season of moult, when, possibly, all the quills were shed at once, as in the ducks and rails of to-day, for example, but they were almost certainly used during the nesting period, and after the fashion of that strange and aberrant bird the hoatzin, which occurs in some parts on the Amazon to-day.

The facts as to the nestlings of this bird may be presented in a condensed fashion as follows:

Hatched in a precocious condition, in a rough nest of sticks constructed amid the boughs of trees overhanging the water, these nestlings quickly display their activity by scrambling out of the nursery and wandering among the branches; using, be it noted, feet, and wings, and beak as organs of locomotion. Now at this stage the index finger is of great length, and terminates in a fleshy pad, overhung by a claw; the hand, indeed, is longer than the forearm. At this stage the developing remiges are represented only by short downy tufts, as in Fig. 1. But the development of the quills is pushed rapidly forwards, at least in so far as the primaries are concerned, and this in order to secure safety against falls, by flight at the earliest possible moment. Be it noted, however, that there is a curious irregularity in this development; for while the innermost quills have grown so far as to form a fan-shaped surface the outermost quills are as yet represented only by downy tufts. Now the reason for this is obvious. If all the quills grew at the same rate the wing would soon reach a stage when it would be useless either for climbing or flight, with disastrous consequences to the individual, useless for climbing because the terminal quills would put the finger tip out of action, so to speak, and for flight, because the area of the wing would be too small to sustain the body even as a parachute. So soon, however, as the inner quills have grown large enough to be useful the outer quills begin to grow, and thereon the rapid absorption of the claw of the index finger follows, and later that of the pollex, and by this time a further notable change has taken place in the wing, for the forearm, growing more rapidly than the hand, now becomes the longest segment of the wing, thus reversing the order seen in the nestling.

This history is in itself extremely interesting, but it acquires a ten-fold interest from the fact that the wings of the gallinaceous birds, touracos, tinamous, and, stranger still, of rhea, pass through precisely similar, though less perfectly developed phases, showing that they must have descended from an arboreal stock. The imperfections in the record are shown in the fact that the index finger is never so long as in the hoatzin at the same developmental stage. In the fowl, for example, the claws are present only during embryonic life; but the same differences in the relative lengths of the forearm and hand are still displayed.

The presence of these claws in the wing, and of the arrested development of the outer primaries, and of the varying proportions of arm, forearm, and hand during development are so many vestiges of earlier, and now obsolete, phases of existence; they are but a few of dozens of such indications of the past. In some cases they appear but as phases of a progressive development, in others they appear as a series of perfectly continuous phases of retrogression. The importance of these phenomena is generally lost sight of, for the theme of evolution by atrophy has not engaged the attention it deserves at the hands of the biologist, though, as some of my readers may remember, it formed the subject of one of the volumes of the International Scientific Series, published a few years ago. Herein, however, the subject is not treated with any degree of thoroughness, and much that is beside the point is introduced.

And now to briefly summarise the facts here passed in review. It has been shown that in tracing out the history of the retrogression of the wing every stage may be met with between the wing of a rounded contour and relatively small area, characteristic of so many non-migratory birds, and the absolute disappearance of the organ, as in æpyornis. What are the factors which determine this dissolution?

According to some authorities the retrogression of the wing, as of other organs, is the direct outcome of disuse. Flight having become no longer necessary the wing, from disuse, has grown smaller and smaller in each generation. In other words, the effects of disuse

are directly transmissible. But there is no more evidence in support of this contention than for that other, and opposite, argument, which, among many, even to-day finds favour, to wit, the increase of an organ in response to the direct effect of use. In other words, that acquired characters are transmissible and transmitted.

Weissmann is, and always has been, one of the most vigorous opponents of this view of the direct effects of disuse. He contends that this work of disintegration is due to "Panmixia," to the cessation of selection. Flight having become, from one cause or another, no longer necessary to obtain a livelihood, birds with indifferent powers of flight, and their offspring, ceased to be handicapped in the struggle for existence, and, interbreeding promiscuously with individuals with large or small wings, soon reduced the standard of efficiency necessary to flight, and brought about the loss of this mode of locomotion, and, in course of time, of the wing altogether. He has also suggested that the decay of the wing, as of other organs, may be due to the malnutrition of the determinants of the wing while in the germ-plasm, whereby less and less material was handed on to the individuals carrying this particular strain of germ-plasm.

There seem to be many and serious objections to this last view, for it is difficult to imagine this process of malnutrition among these particular determinants occurring simultaneously among a considerable number of individuals of the same species; or even to conceive of this taking place in a single individual of some "incipient species." It must surely be something more than mere coincidence that this flightlessness is always correlated with certain external, environmental conditions—an abundance of food, obtainable without flight, freedom from enemies, and from extremes of climate.

It is conceivable, of course, that this tendency to flightlessness is ever present, and is indicated by all those individuals which fall below the average standard of wing measurement. It is further possible that this is also a germinal variation, and once started tends to continue until the loss of the whole wing results. Where flight is imperative this would mean the speedy extermination of the individuals so varying, and this before the process of degeneration had attained any appreciable amount. Where, on the other hand, the conditions of existence were favourable, when sufficient sustenance could be obtained without flight, and where other factors of existence were not unduly hard, the wingless condition would result.

The great auk and the penguin are stumbling blocks in the way of this interpretation. If the course of retrogression once begun is continuous, they would have arrived ere now at, or have been well on the way towards, the condition of winglessness seen in æpyornis, and, eventually, in the moas. But both in auks and penguins the downward path was not only arrested, but, in the penguin, by a change of function the whole wing became transformed!

By what mechanism, by what process of change, are new determinants introduced into a decadent organ? We use the phrase "decadent organ" with caution, for while it seems appropriate enough to apply to the case of the wing we do know enough of the history of the evolution of the paddle of the whale and turtle to enable us to do more than speculate as to its origin. To this aspect of the matter, however, we propose to return on a subsequent occasion.

Zulu Music.

SOME time ago an essay by Professor C. W. Sabine referred the origin of a musical scale to the environment of early peoples. The duration of audibility of a sound depends first on its loudness and pitch, then in a small degree on the shape of the confined space in which the sound is made, and in a very large degree on the volume of the spaces and on the material of which its walls are composed. Other things being equal, the duration of audibility *and the overlapping of successive sounds*, and, therefore, the expression of harmony in single part music are proportional to the dimensions of the room, be it dwelling-house or temple. It will be seen that Professor Sabine's theory is based on the reflection (and consequent mingling of sounds) from the walls of the places where the sounds are heard. In open spaces there would be no reflections of any kind, no resonance. Therefore savage or primitive races, though they might possess a sense of rhythm, would be very slow to develop a musical scale. In Europe, on the other hand, we find the musical scale most rapidly developing among the stone-dwelling peoples along the shore of the Mediterranean, and the development kept pace with the increased size of the dwellings and temples.

Whatever may be the validity of Professor Sabine's theory, the value of recording the musical development of primitive peoples is beyond question, and a most instructive essay cognate to the subject appears in the "Annals of the Natal Government Museum" (Vol. I., Part 3) under the title of "A Short Study on Zulu Music," by the Rev. Father Franz Mayr. Father Mayr remarks that in spite of the good musical ear of these Zulus, and their great fondness for playing musical instruments and singing, their proficiency in either instrumental or vocal music is small. Their original native music will, however, soon be lost, because European music, and the European concertina, and the American gramophone are penetrating every part of the country, and are taking the place of the original instruments and their products.

Father Mayr thus describes the native musical instruments:—

(1) Umqangala, or stringed bow. It is made of a bent stick or reed, with a string of ox-tendon stretched tightly across. The bows vary considerably in size and sometimes they may be ornamented; in the specimen shown in Fig. 3 the surface of the reed is covered with engravings. In using the instrument, one end of the bow is held by the lips of the player, and the other end with the left hand. The string is twanged with the thumb of the right hand, and notes of different pitch are produced by means of the fingers of the left hand pressing on the string. It would appear that the mouth of the performer acts as a resonator (*vide* Pl. XLIV).

(2) Ugubu, or ugumbu, is a stringed bow with a calabash attached towards one end (Fig. 10). A small portion of the calabash is cut off square at the free end. The bow is held vertically, and the opening of the calabash is pressed against the chest with the left hand, while with the right hand the string is struck with a small stick. The pitch is altered by the fingers of the left hand pressing on the string, while the tone is varied by the varying pressure of the calabash against the chest.

(3) Uqwabe is a stringed bow with the string tied down at the middle towards the bow, and at this place a large calabash is fixed (Fig. 11). The opening of the

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calabash is slightly pressed against the chest of the player as in the ugubu, but the bow is sometimes held horizontally instead of upright. With a small stick the player strikes the string alternately on each side of the calabash, and the pitch is changed by pressing the string with the first finger of the left hand.

Pl. XLIII.

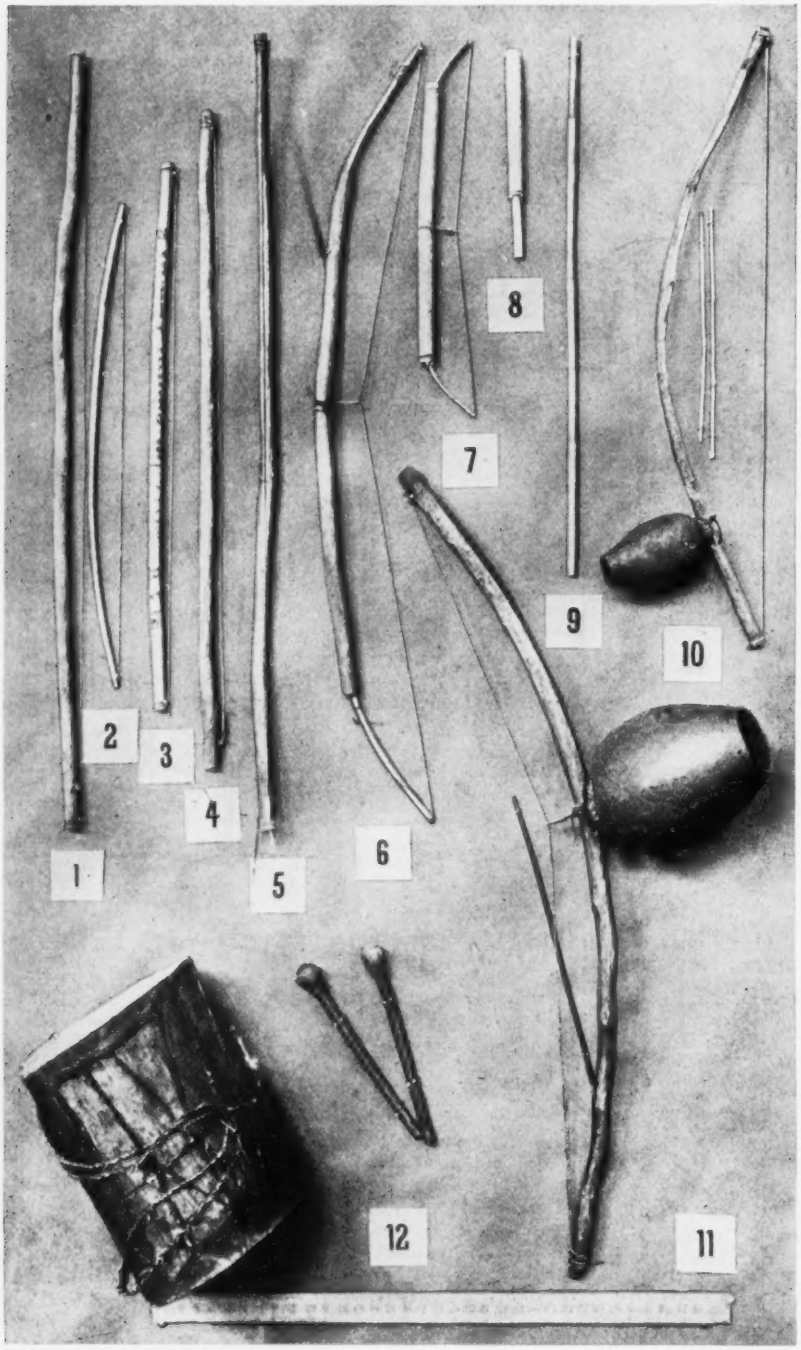


Photo. by Natal Railway Dept.] [*Adlard & Son, Impr.*

Zulu Musical Instruments.

1-3, Umqangala; 4. Side view of Ugwala, with split quill at the bottom; 5, Front view of Ugwala; 6-7, Isitontolo; 8, Igemfe; 9, Umtshingo; 10, Ugubu or Ugumbu; 11, Uqwabe; 12, Isigubu. (A yard measure was placed below to indicate size.)

(4) Ugwala is in form and size like the umqangala, except that at one end the string of ox-tendon is attached to the split quill of a feather. The other end of the quill is either bound down to the end of the bow by a thin strip of skin, with a piece of quill projecting freely beyond, or it is passed through a hole in the wood, in which it is tightly wedged by a peg of wood. Figs. 4 and 5 give side and front views of this instrument; the split quill is seen at the bottom of the string.

The instrument appears to be a difficult one to use, and women are the chief performers. The mouth is placed over the split quill and a whistling sound is produced by the breath; the pitch is varied by pressing the string at the opposite end with the fingers of the left hand.

(5) Isitontolo. This instrument has been adopted from the Basutus. It is illustrated in Figs. 6 and 7. It often consists of a reed (Fig. 7) through which a flexible stick is passed, and a string of ox-tendon is stretched tightly across. The string is tied down in the middle towards the bow. The reed may be replaced by a curved stick, into the ends of which are fixed short flexible sticks (Fig. 6). In playing the instrument one end of the middle thicker portion is placed against the mouth, as in the case of the umqangala, while the string is twanged with the right hand. The mouth acts as a resonator, while the pitch can be altered by the fingers of the left hand pressing on the string.

(6) Umtshingo, or reed-pipe whistle. The end placed to the mouth is cut obliquely (Fig. 9), the other end is cut transversely. The lower end is more or less closed with a finger, and the pitch can be regulated. As a rule, two whistles are played together by two players, one taking the lead and the other responding.

(7) Igemfe is another form of whistle. It is made of a large reed fitting over one of smaller diameter (Fig. 8). It is played like the umtshingo.

(8) Isigubu, or drum (Fig. 12). A piece of the trunk of a tree, about eighteen inches long and one to two feet in diameter, is hollowed out into a cylinder. The Umsenge, or Cabbage Tree (*Cussonia spicata*), or the Umhlonhlo (*Euphorbia grandidens*) are often selected on account of the softness of the wood. Calf or goat skin is stretched

across the two ends and tied tightly together by strips of skin or tendon. The drum is beaten with small drum-sticks.

These eight instruments are still in use to a small extent; but the music elicited from them by the untutored Zulu could seldom please a European, for in most cases Zulu instrumental music is extremely monotonous, and with very little value in melody or rhythm. Except in the case of a drum the volume of sound produced is very small, and the performer himself is the only person who derives any enjoyment from the music.

Zulu songs are either of a public or a private character. The private songs, like the poems which every educated Japanese can write, are those which a Zulu will chant to commemorate some event of their lives or the lives of their friends. They may be even like the songs which some children will sing about the happenings of their little day. There are more public songs which are sung at the "Feast of the First Fruits"—"ukwetshwama," or at royal marriages, or which are war songs or tribal songs such as are possessed by every chief and tribe. But there is great freedom in rendering the songs, and considerable alteration is made in the tune at different times, but the general meaning of the text and the main notes of the air are retained.

Pl. XLIV.

[*Adlard & Son, Impr.*

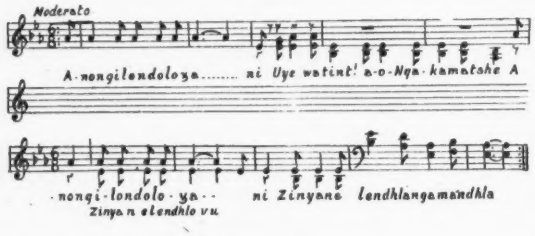
A Native Orchestra.

Names of Instruments.—Back row, beginning on the left: Uqwabe, Umqangala, Igemfe; Front Row: Ugubu, Isitontolo, Ugwala.

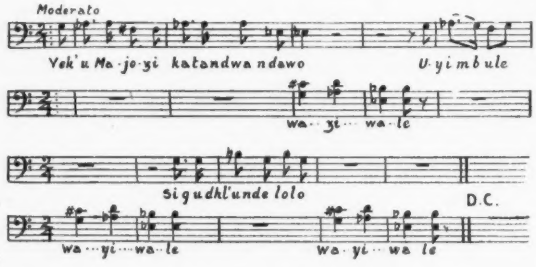
The time is very much "tempo rubato." Rhythm is marked by action such as stamping the feet, clapping hands, brandishing a dancing stick, or by movements of the body. In singing a war song—"igama lempi"—the men stand in a row, or rows, the chief in the middle of the front row, and on either side the women and children keep time with their hands as the men stamp their feet.

The melodies have, as a rule, a descending tendency, each musical sentence beginning at a high pitch and descending towards its end. Fourths are intervals very frequently used, also minor keys and mournful cadences, which are strange, difficult and barbarous to ears accustomed to modern music. The harmony of the native tunes, in correspondence with the melody, is equally mournful. The Zulus fall without effort into a second or third vocal part for accompanying the tune, and the absence of discords is most notable.

The following song comes from Cetewayo's time and is widely used as the "isingeniso" or first song at a marriage when the bride makes her first appearance with her friends at the place for dancing—"isicawu." The bride takes the lead, and the whole song and dance are rendered slowly.



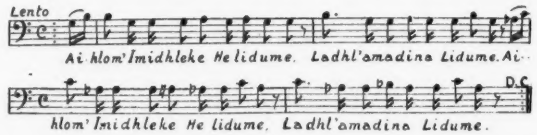
Here follows a chief's song :—

Yek uMajozi katandwa	Poor Majozi is not loved,
Wayiwa le, [ndawo,	He was rejected far away,
Uyimbule,	He is a lion,
Wayiwa le,	He was rejected far away,
Sigudhl'unde lolo,	We pass this long range,*
Wayiwa le.	He was rejected far away.

Majozi is the surname of chief Ngoza, and the song may be called iketo lenkosi, chief's song. It is sung by men only, and sounds impressive on account of the rude, powerful rendering and the strange action.

The composers of chiefs' songs are invariably men, not women; in fact, very few songs originate from women.

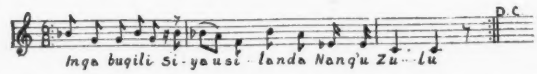
Aihlom' Imidhleke,	Let the Imidhleke prepare for war,
He lidume,	Let the thunder of war roll,
Ladhl'amadina,	The dinner has been eaten,
Lidume.	Let the thunder of war roll.

* Drakensberg Mountains.



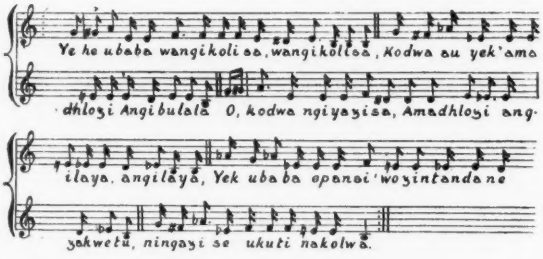
This is an "ihubo lempi," war-song, of Hennhemu, father of Mveli, the present chief of the Mafunzi tribe, in the Zwaartkop location, near Pietermaritzburg.

Inqa buqili	See the crafty hiding themselves,
Siyausilanda,	We will fetch their cattle,
Nang'u Zulu.	Here we are (we Zulus).



War song used in some parts of Zululand, which was composed after a fight with the Swazis at the beginning of Pondo's reign.

Ye he ubaba wangikolisa,	Well my father gave me satisfaction,
Kodwa au yek'amadhlozi	But, alas, the spirits (of the
Angibulala.	Kill me. [dead)
O, kodwa ngiyazisa,	And yet I praise them,
Amadhlozi angilaya,	The spirits inform me,
Yek ubaba epansi,	Oh! my father is dead,
Wo zintandane zakwetu,	Poor orphan children,
Ning'azise ukuti nakolwa.	Tell me do you believe (that the spirits inform me).


Ye he ubaba wangikoli sa, wangikolisa, Kodwa au yek'ama
dhlozi Angibulala O, kodwa ngiyazisa, Amadhlozi ang-
ilaya. angilaya, Yek ubaba epansi wo zintandane
zakwetu, ningazi se ukuti nakolwa.

This is an "isililo," or lamentation of a witch-doctor. It is sung without rhythm or action.

Father Mayr concludes: "The literal translation gives some idea of the general significance of the text; but a great deal of explanation would be required to make the meaning clearer. The intention was to give a few samples of Zulu songs of different kinds, in order to illustrate the general character of native music. It may be added that with the kind assistance of Dr. Alan Miller the songs were carefully taken down, partly from the lips of the singers, and partly from phonograph records." In adapting the songs to modern musical notation the temptation to doctor them had sternly to be resisted.

A RATHER curious fact emerges from the report in the *Journal Officiel* of last year's census in France, which is that in that country, where the signs of decadence are usually believed to show themselves in a declining population, there was in 1908 an excess of births over deaths amounting to 46,411. In two years prior to that, in 1900 and in 1907, there was an excess of deaths over births. But the excess of births over deaths last year was higher than the average for the preceding ten years. It is noteworthy that for 1908 the number of deaths was the smallest in eleven years, and considerably smaller, of course, than the average for ten preceding years. The birthrate then is a recovery, and marriages are the largest in eleven years, 5 per cent. greater than the average for the decade. These are the facts whatever the explanation may be.

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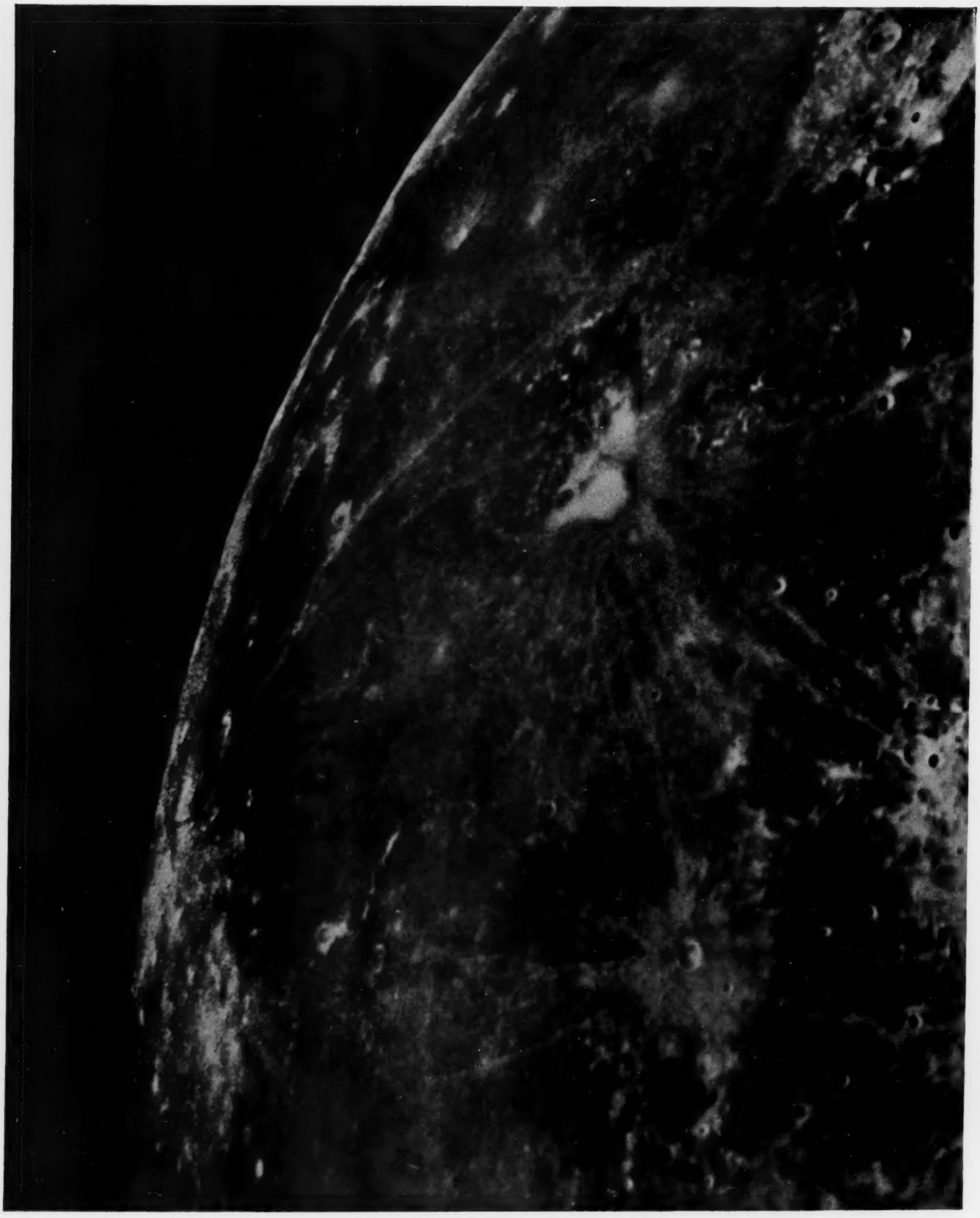

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The Moon.

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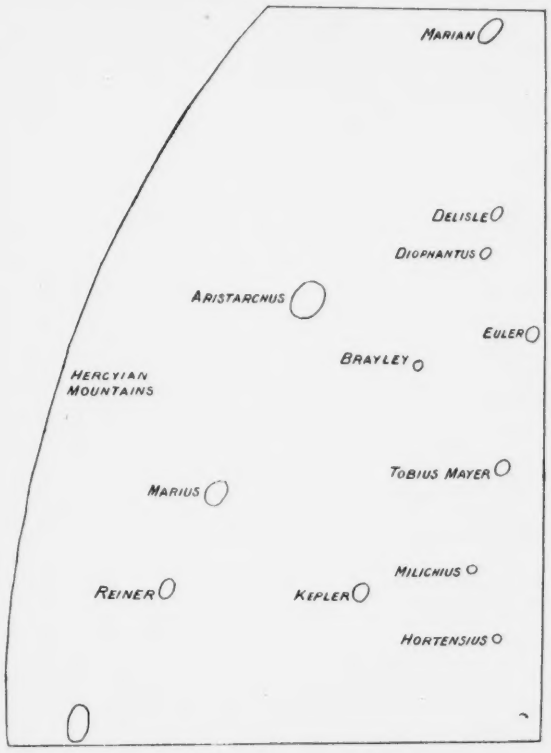
Photograph of the Moon.

THE dark portion of this, the N.E., region of the moon forms the *Oceanus Procellarum*, which is the largest of the great dusky lunar plains. Many ridges may be discerned at suitable times on the surface of this *Mare*, and there are several striking ray systems centring in Aristarchus, Kepler, and Copernicus, but the latter is not included in the present map.

Aristarchus is undoubtedly the principal feature since it is a formation of almost unique brilliancy, having been sometimes mistaken for an active volcano. It shines with suggestive strength before the sunlight reaches it, and is pretty conspicuous, for it often attracts the eye to the dark part of the moon, when it can



be seen glowing unmistakably even in a small instrument. It is 28 miles in diameter, with a surrounding wall about 2,500 ft. above the inner and 7,500 ft. above the outer surface. It has a very luminous central cone about 1,280 ft. high. Webb says Aristarchus is visible to the naked eye on the bright side of the moon and variations in its light have been suspected, but they have never been sufficiently investigated or satisfactorily explained. The *Harbinger Mountains* lie about 45 miles W.N.W., and these come into light about 10 days after new and just precede the dazzling Aristarchus.

Kepler forms another conspicuous centre of light-rays. It is nearly 22 miles in diameter, and the interior is depressed some 10,000 ft. below the bright wall which environs it. Gruithuisen found its aspect dissimilar even under identical illumination. Neison says that the central peak of Kepler is one of the best determined points on the moon. The ring-plain forming Kepler lies in a region which has been comparatively undisturbed, for a level condition of surface surrounds it and the nebulous streaks radiating from it may be readily traced and figured.

Marius forms a ring-plain 27 miles in diameter. It has a craterlet on the N.W. of the interior floor. A number of small craterlets lie W. of this object, and some hills are conspicuous when this region is near the terminator.

Tobius Mayer is 9,700 ft. deep near W. side.

Euler is notable for its light-rays; it is 19 miles across and almost 6,000 ft. deep.

Hercynian Mountains extend over 11 degrees of longitude and show a number of massive peaks more than 7,000 ft. in height.

Diophantes is a small ring-plain about 12 miles in diameter lying near *Delisle*, a somewhat larger object of same class. The latter has a central peak and a crater on N. wall.

Milichius is a large crater-plain, and, like *Hortensius*, lies in a formerly much agitated region of the lunar surface.

For further details of objects Webb's and Neison's works should be consulted.

Photograph of the Moon.—Part VII.

(Omitted from July issue.)

THE photograph of the moon in the July number of "KNOWLEDGE," represents a portion of the N.E. quadrant which contains one of the most celebrated and well-known ring plains on our satellite. The chief objects of interest are as follows:—

Plato, a great walled plain over 60 miles in diameter with many terraces on the exterior. The peaks on the west and north are very lofty, one rising to a height of 7,258 ft. On the south the crest of the wall is about 3,000 ft. The surface of the plain contains many light grey streaks and small round, white spots. Ten of these spots are minute crater-like cones with bright, steep, exterior walls and a central crater on the summit; six others probably belong to the same class. Twenty-seven light streaks have been observed crossing each other on the floor of Plato, they appear to vary in brightness and visibility. The tint of the floor itself also undergoes a regular change which cannot be explained, except, perhaps, by ascribing it to an actual variation in the brightness of the surface.

Teneriffe Mountains extend for 60 miles, rising at one point to a height of 2,400 ft., and at another 8,000 ft.

Fontenelle, a ring-plain over 22 miles in diameter, with walls rising in some parts 6,069 ft. above the interior, which contains a small central peak.

Timæus, a fine ring-plain with walls 4,500 ft. high. It is surrounded by many short light streaks and on the east side by a mass of mountains.

Ipigenes, a large ring-plain with two high peaks and two craters on its walls. A mountain chain, rising at one point 4,000 ft., extends from it to Timæus.

Anaxagoras, a ring-plain over 31 miles in diameter. The wall is gently sloping and terraced on the exterior

and steep towards the interior. Northwards extends a long mountain chain.

Philolaus, a ring-plain about 45 miles in diameter, with a terraced wall rising 11,721 ft. on the west, and a central mountain. Southwards are long mountain chains.

Anaximander, a ring-plain 39 miles in diameter, with walls rising 6,414 ft. on the west, and 9,714 ft. on the south-west. On the north are many large and deep ring-plains.

Pythagoras, a large walled plain 95 miles in diameter, with walls 16,940 ft. high in some parts. Around are a number of ridges and low hills.

Condamine, a ring-plain 23 miles in diameter, on the north border of the highlands of the Sinus Iridum. Its walls are broken by a number of crater-like depressions.

Maupertius, a walled plain between mountains. Probably 2,800 ft. beneath the level of the highlands of the Sinus Iridum at this point. It contains six small mountains, the highest about 1,150 ft.

Sharp, a ring-plain nearly 24 miles in diameter, with a bright central mountain and steep r gged walls, rising on the west 9,624 ft. above the interior.

Bianchini, a ring-plain with a wall rising 8,460 ft. on the west, but much lower towards the south.

Foucault, a small ring-plain of considerable depth, with a central mountain.

Harpalus, a large isolated ring-plain with bright walls, which rise on the east 2,801 ft. above the Mare Trigoris and sink 15,853 ft. to the floor beneath them. It is one of the deepest formations on the whole moon.

Sinus Iridum, a large bay of the Mare Imbrium, called by Mädler "the most gorgeous and magnificent of lunar formations." It is bordered by lofty cliffs and peaks rising to a height of 15,000 to 20,000 ft. The bay is 134 miles in breadth and 83 miles in depth, with an area of 92,000 square miles. The western portion is covered with grey streaks and has a greenish tint. Irregularities on its surface are not numerous and are never seen very distinctly.

Mitosis in Higher Plants.
(With Short Notes on Technique.)

By H. A. HAIG, M.B., B.S.

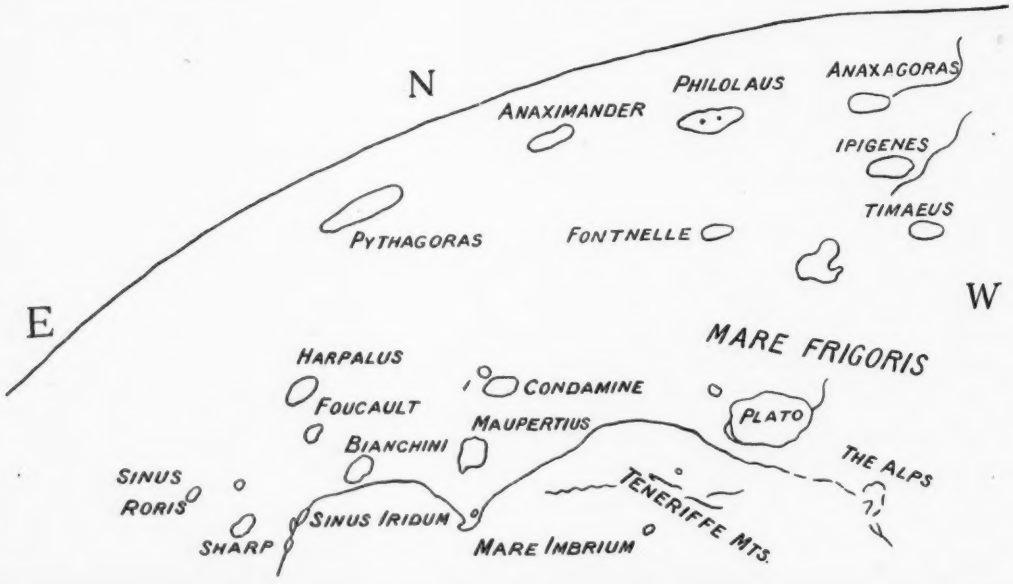
(*Continued from p.* 286.)

SECTION IV.

Summary: The achromatic spindle. Arrangement of the chromosomes into an equatorial plate: Splitting of the primary chromosomes.

I have further back referred to the inability to discover any structures comparable to centrosomes in Hyacinthus or Allium, and even Lilium does not appear to have them present. The amphiaster* or nuclear spindle does not really become obvious until the primary chromosomes have undergone orientation and lie in or nearly in the equatorial plane of the cell; and at this time, or just previous to it, careful observation will usually make out fibrillæ of rather greater refractility than the clear hyaloplasm, running in a direction parallel to the long axis of the cell. In fact, the spindle-fibres appear to arise as intra-nuclear formations, and, although they converge approximately to two points at opposite poles of the cell, there is no appearance of astral rays comparable to those found at the poles in animal-cells. [In some plants (Equisetum) the spindle appears to be multipolar, the mantle-fibres converging at each end of the spindle to a number of points situated on a transverse plane. But this is unusual.] The origin of the spindle-fibres, more especially the so-called mantle fibres, has been a subject of much investigation and hypothesis; some observers have thought that the linin elements of the nucleus go to the formation of these fibrils and that the axial fibres of less refractility and contractile power originated in the remaining hyaloplasm. The so-called kinoplasm has also been credited with the production of the spindle-fibres, but I have elsewhere pointed out the probability of the absence of any such portion of the cytoplasm, at any rate in the

* The term "Amphiaster" is here incorrectly applied to the nuclear spindle, as there are no astral rays; it is, however, a convenient term.



higher plants. In the complete spindle of the monaster stage, lines and streaks of greater refractility can certainly be seen, and it is possible to make out in good preparations that the secondary chromosomes travel along these lines of a presumably contractile nature* (see Figs. 17 and 25). Other investigators have attempted to show that the centrosomes, or the area in cells where these would be found, if present, exert an attractive influence (chemotaxis) upon the daughter-chromosomes, but the hypothesis of the contractile

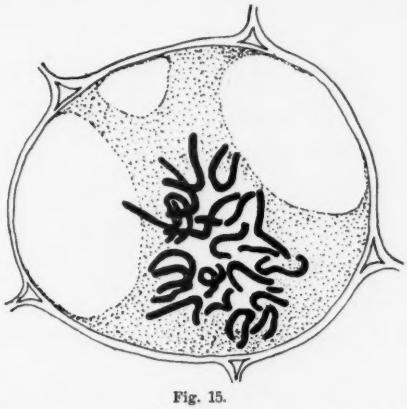


Fig. 15.

The "monaster" or "equatorial" stage from root-tip of Hyacinthus (transverse section) (drawn from a photo-micrograph).

nature of the mantle-fibres is simpler and more likely to be nearer the truth. The chemotactic theory has, however, many supporters.

The chemical nature of the fibrils of the spindle does not in this present study concern us, suffice it to say that they are of a similar chemical and physical constitution to the ectoplasm of the general cell; no granules are visible in them until the time when the cell-plate begins to form, when small highly-refractile spots arise in the middle of each fibril and eventually

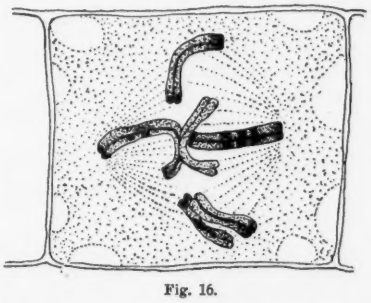


Fig. 16.

A cell from root-tip of Hyacinthus showing in longitudinal optical section the double nature of the primary chromosomes. The achromatic spindle is well-defined (drawn under 1/12 "oil-immersion).

coalesce; we shall speak of this again when we come to the consideration of the formation of the cell-plate.

The mantle-fibres are remarkable in that they appear to possess contractile power, pointing to a constitution somewhat like that existing in the fibrillæ of unstriped muscular fibres; that the appearance of greater refractility in some of the achromatic fibrils is not due simply to change during preparations of the sections is now well determined, since in some cells (Embryo-sac of Lilium, Allium, Equisetum spores) separate cones of these mantle-fibres can be distinguished, each cone being associated as a rule with a single chromosome. (See Fig. 17.)

Some observers have described these fibrils as lying just outside the nucleus in the earlier stages as a network which gradually makes its way into the interior of the nucleus, but I have not been able to verify this in the plants I have studied. It seems to me likely that they are not far removed in constitution from the main non-granular groundwork of the cytopalsm (spongioplasm), for in the end-stages they appear to form fibrillæ continuous with the cytoplasm and become converted into that substance; and in the early endosperm of Caltha palustris the achromatic fibrils persist for a long time after the cell-plate is complete, become later on granular and take on all the characters of typical cytoplasmic "bridles" (see Fig. 34). This accords

Fig. 17.

The equatorial plate of chromosomes in optical longitudinal section. The 'mantle-fibres" of the spindle are well-defined (drawn from a photo-micrograph).

well with the most recent theories of the constitution of the elements composing the protoplast, viz., that they all have a common basis and that any one of them, within limits, may be easily transformed into any other; on these lines it is quite orthodox to suppose that the nucleolar substance can be transformed into chromatin, and thus form a reserve-material for the formation of the nuclein of the chromosomes (see *supra*).

I have previously referred to the fact that one can distinguish a refractile spot at each pole of the spindle; in one of my preparations* the position and appearance of these spots for some time led me to think that they represented true centrosomes, but the chromosomes were broken and not complete, so that it was quite possible that a small portion of a chromosome at each end was detached and came to lie in a polar position. Moreover, no astral rays could be distinguished, and I have come to the conclusion that these refractile spots are merely the optical effect produced by the convergence of the achromatic fibrils at the poles. (A photograph of this preparation was obtained, but was inconclusive.) Examination of other figures in the same section led me finally to regard the

* See Haidenhain's beautiful explanation of the mechanism of mitosis in Wilson's "The Cell in Inheritance and Development."

* From root-tip of Hyacinthus.

appearance as due to no definite formed bodies at these spots comparable to the blepharoplasts or centrosomes of lower plants. (Microsomata in the cytoplasm may also cause confusion in this respect.)

In the plants which have been selected for the present investigation the achromatic spindle is a much more evident structure in Hyacinthus than it is in Allium; this is so, probably, on account of the greater contrast between cytoplasm and spindle in the former plant, where the protoplasm of the main cell is very granular. Moreover, mantle-fibres are more apparent in Hyacinthus; this is also the case in Larix europæa, where the spindle is a very prominent feature of the mitotic figure. During the later stages, when the cell-plate is beginning to form, the achromatic fibrils are very distinct both in Larix and Hyacinthus, and persist for some time, as we have seen, going to form, when the cell-plate is complete, cytoplasmic bridles in adjacent cells.

ARRANGEMENT OF THE PRIMARY CHROMOSOMES INTO AN EQUATORIAL PLATE.

Soon after the primary chromosomes have been formed by the breaking up of the spireme, and the

Fig. 18.

Cleavage and separation of the chromosomes (Allium, root-tip).

orientation of the resulting parts into a plane transverse to the long axis of the cell, they gradually come to assume individually a V or U shape, the latter being the commoner form; the bend of the U is, by the traction, exerted by the achromatic fibrils, drawn towards the centre of the median equatorial plane, so that finally we have a system of U-shaped chromosomes arranged with their bends adjacent to one another and pointing towards the centre of the equatorial plane. In longitudinal sections we find, however, that as a rule there is a tendency for the free ends of the chromosomes to project somewhat irregularly from either side of the median plane (see Figs. 16 and 17), and that the typical symmetrical position of the loops, as described in most text-books is a rare state of things even in very careful preparations; and, as a matter of fact, it is probable that a certain amount of traction is being exerted upon the free ends of the loops by the mantle-fibres, so that it would be almost impossible for the symmetrical equatorial arrangement to persist for any length of time. However, as a rule, the bends of the loops are directed approximately towards the centre of the median plane, although the free ends are apt to lie somewhat irregularly.

We have previously seen that the spireme is longitudinally split so that during earlier stages two bands of chromatin-granules may be detected lying side by side; under the 1/12″ oil-immersion and higher objectives, the primary chromosomes are seen to present the same double constitution, although the two halves lie so close together that resolution is difficult. In transverse sections, showing the monaster stage in surface view, we cannot, as a rule, see this doubling of the chromosomes, but longitudinal sections will

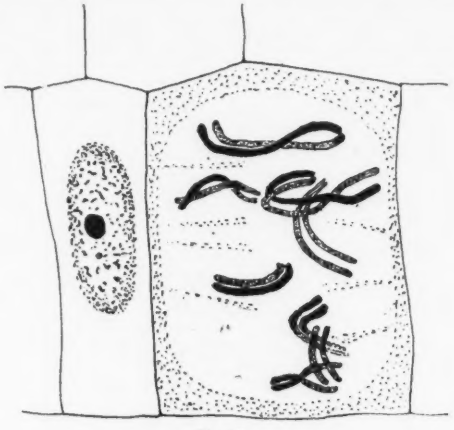


Fig. 19.

Cleavage and separation of the chromosomes (Allium, root-tip, 1/12″ oil-immersion).

show many instances of it since we are then viewing the chromosomes in a plane parallel to the plane of fission. Sections which have been stained with gentian-violet or safranin and left for some considerable time show this fission well, especially if the staining has not been too intense.

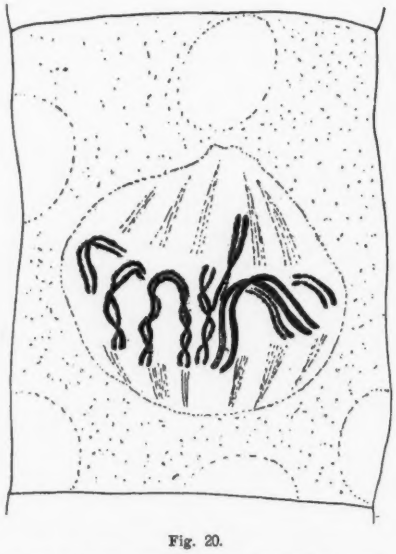


Fig. 20.

Cleavage of the primary chromosomes in Hyacinthus root-tip. Some of them are twisted, a common occurrence after complete fission.

A point, which has not yet been definitely settled, is the cause of the shape taken on by each primary chromosome, viz., the U-shape; it is possible that the free ends of the loop are attached to mantle-fibres, and that the tension exerted by these tends to draw the ends towards one another. Some such mechanism must be at work, for the chromosomes have no special elasticity

of their own wherewith to assume the loop form, unless the linin thread which connects the separate chromatin granules has elastic properties.

Thus, to recapitulate, it seems that after the spireme has split up into the primary chromosomes, the tensions exerted by the mantle-fibres of the nuclear spindle come into play, and first of all by a sort of guiding and pulling action the chromosomes are orientated into an approximately transverse median plane, then by the same action they are arranged each one with the bend of the loop towards the centre of that plane, and the free ends pointing away from it. The shape of the loop may possibly be determined by the tensions exerted by these fibrils, and, in fact, the fact that the free ends of the chromosomes tend to project from the equatorial plane seems to point to a definite attachment of them to fibres of the achromatic spindle.

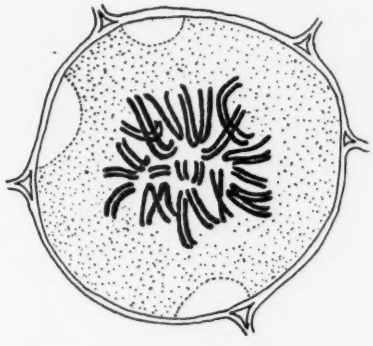


Fig. 21.

Cleavage of chromosomes as seen in a transverse section (Hyacinthus, root tip).

Fig. 22.

Separation of secondary chromosomes in a cell of root-tip of Hyacinthus. The truncated nuclear spindle is well-marked.

THE LONGITUDINAL CLEAVAGE (MANIFEST FISSION) OF THE PRIMARY CHROMOSOMES.

(The following facts have been taken from observations upon Allium and Hyacinthus.)

The primary chromosomes lie approximately in the equatorial position for some little time, and then occurs the phenomenon in each chromosome of longitudinal fission*; that is cleavage parallel to the axis passing from end to end along the linin thread. In Allium and Hyacinthus I have been able to make out this splitting very clearly (see Figs. 16 to 21), but was unable to obtain a photograph on account of difficulty in retaining a clear focus during exposure.

In Hyacinthus a photograph was obtained showing, in optical section, the stage just after fission (see Fig. 17), and one was also obtained from Allium at a somewhat later stage when the secondary loops are just beginning to travel away from one another. (See photo-micrograph of Plate in Part I., last issue.)

In Allium (epiblemal cells of root-tip) just after fission

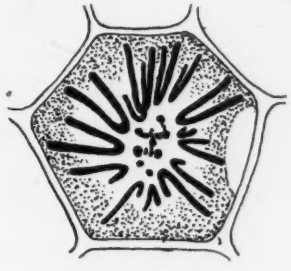


Fig. 23.

A rosette of secondary chromosomes as seen in a transverse section.

a condition is present not unlike that obtaining in heterotypical mitosis, viz., one where a ring-shaped chromosome is seen; but the connected ends soon separate and the daughter-loops travel apart shortly afterwards.

There is at this stage evidence pointing to the correctness of the assumption that mantle-fibres are connected to both free ends and bend of each daughter-chromosome; for the bends of the loops are soon drawn away from the centre and come to lie at the outer surface of the spindle, and this movement does not seem explainable except by the hypothesis just mentioned; for as I have elsewhere pointed out there does not seem

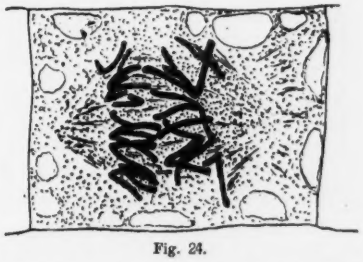


Fig. 24.

Further divergence of the daughter-loops (root-tip Hyacinthus).

to be any conclusive evidence for the assumption of an attraction centre at either of the poles of the spindles.

Whatever may be the value of these hypotheses, it is certain that much remains doubtful with regard to the actual mechanism of mitosis; the discovery, however, of the contractile nature of the mantle-fibres of the achromatic spindle is perhaps one of the most important results of recent investigations into this mechanism, for by the agency of these fibres many of the movements of the chromosomes can be explained. Several of the photo-micrographs from my preparations show the fibres distinctly as refractile bands lying in the more homogeneous parts of the spindle. (See last issue.)

* That is, the more obvious fission preparatory to separation of the secondary loops; we have already seen that fission occurs even in the granule stage of the spireme.

XUM

SECTION V.

Summary: Separation of the Secondary chromosomes: The diaster stage and involution phases: Subsequent fate of the achromatic spindle: Formation of the cell-plate.

After the longitudinal cleavage of the primary chromosomes occurs a short period during which matters are quiescent: then the loops resulting from this

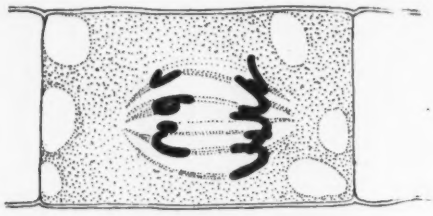


Fig. 25.

A similar stage to Fig. 24, but from root-tip of Allium. Mantle-fibres of spindle well-defined.

cleavage begin to separate from one another, the bends parting company first of all. The free ends of the loops resulting from the cleavage lie close together until the bends are a good way apart, giving a sort of false appearance which might be taken to represent

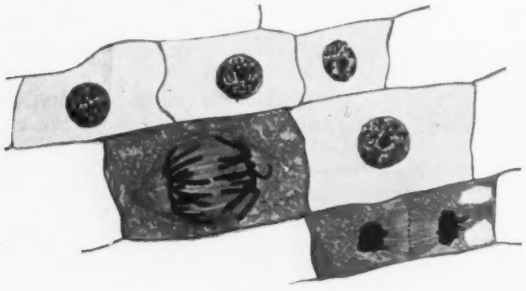


Fig. 26.

Two cells from root-tip of Nymphæa, one showing divergence of daughter-loops, the other an end-stage with signs of the rudimentary cell-plate.

a heterotypical division*. However no true ring-chromosomes are formed and the free ends soon separate from one another.

It appears that the mantle-fibres of the nuclear spindle are attached along the whole length of each daugh-

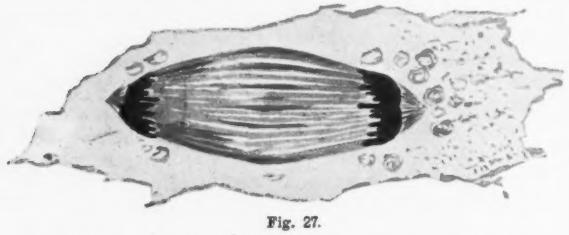


Fig. 27.

A late diaster-stage from cortical cell of young cone of Larix.

ter-chromosome, or at least to the bend and the two free ends; moreover, from one or two of my preparations, it seems that distinct separate groups of these mantle-fibres are associated with each chromosome, the intervening spaces being clear and free from the contractile fibres. (See Figs. 17, 25.)

The mechanism which now follows can be very clearly followed in Allium and Hyacinthus, and also in the early divisions of the embryo-sac nucleus of Lilium; the mantle-fibres appear to shorten and drag with them the daughter-chromosomes, so that we have two distinct systems of secondary chromosomes travelling apart, with their free-ends pointing towards the circumference of the equatorial plane of the spindle. (See Figs. 22, 24, 25.) The secondary loops in Allium have rather obtuse bends, but those of Hyacinthus are

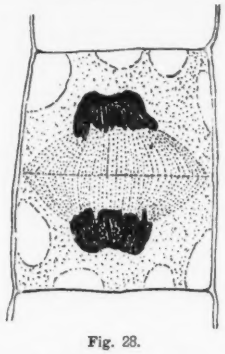


Fig. 28.

An end-stage from cell of root-tip of Hyacinthus. The spindle-fibres are well-defined and the cell-plate has been formed.

very acutely bent, having the V-shapes well-marked. This may possibly be due to the effect of the traction of the mantle-fibres at the bend being greater than that at the free-ends, causing a sharper curve; but of this I am not certain.

As the two systems of loops are pulled apart there are left between them achromatic connecting fibrils (so-called interzonal fibres) in no wise different in microscopical structure from those between the loops and the poles of the spindle; these fibres, however, pro-

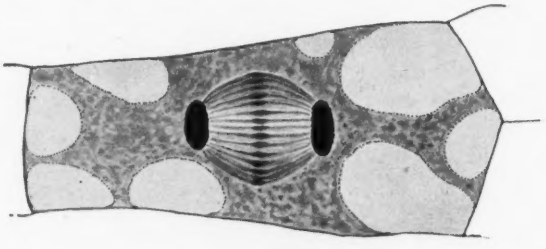


Fig. 29.

An early cell-plate stage from cortical cell of Larix cone. The central thickenings on the spindle-fibres are shown before fusion has occurred (drawn partly from a photo-micrograph and from observation).

bably exert but little tension, serving mainly to keep the free ends of the loops within the active zone. The main mass of the mantle-fibres lies now between the two systems of loops and the spindle-poles.

THE DIASTER STAGE AND INVOLUTION PHASES.

When the two systems of daughter-chromosomes have reached opposite poles of the spindle (see Fig. 27) they remain for a short time quiescent, and then involution commences; the polar masses of mantle-fibres soon become obliterated, either being absorbed or else entering into the formation of the linin network. There

* In Allium this is very marked.

is nothing further of note in the diaster-stage, beyond the fact that the free ends of the daughter-chromosomes are usually directed towards the median plane of the spindle for a rather long time, and this suggests the fact that guiding-fibres are still attached to them; subsequently the free ends pass more and more towards the poles and then true involution of the chromosomes occurs. Involution consists in the end-to-end union of

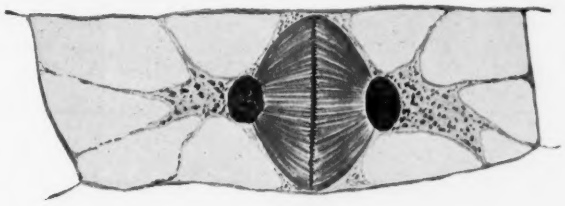


Fig. 30.
A cell from the late endosperm of Caltha showing an end-stage with two complete daughter-nuclei and complete cell-plate in optical section.

the secondary chromosomes, so that the appearance of a spireme at each pole of the spindle is produced (dispireme stage). Then occurs fragmentation of the spireme into the granules of chromatin and re-appearance of nucleoli; how the latter are formed is a point of much uncertainty, but probably an inverse chemical process occurs with the production of para-nuclein from part of the chromatin. These are points beyond the scope of this investigation.

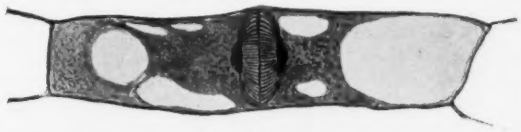


Fig. 31.
A cell from medulla of Larix cone (early) showing a completed end-stage with contraction of the spindle and approximation of daughter-nuclei.

SUBSEQUENT FATE OF THE AMPHIASTER AND FORMATION OF THE CELL-PLATE.

I have deemed it necessary to include a description of the fate of the spindle and formation of the cell-plate in the plants studied (Allium, Hyacinthus, Larix, and Caltha), for these are matters of great interest from the cytological point of view; the following is a brief outline of the main facts :—

The amphiaster persists for a time without much change in its general appearance, but soon contraction

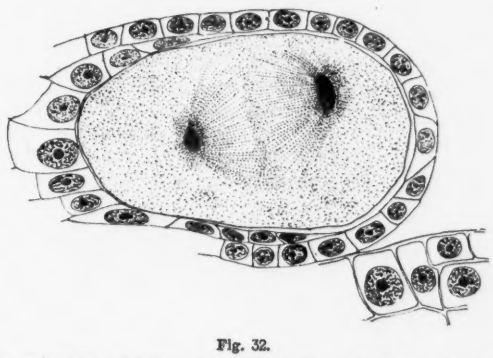


Fig. 32.
The embryo-sac of Lilium martagon at the end of the first mitotic division. The nuclear spindle-fibres are very obvious (drawn from a photo-micrograph).

occurs in the longitudinal axis, this resulting in a bulging of the spindle towards the side walls of the cell; in Larix this change is very marked (see Fig. 31), and naturally as the contraction proceeds the daughter-nuclei are drawn towards one another. By the time the lateral aspects of the spindle have almost reached the side walls of the cell a faint transverse line of higher refractile power than the rest of the spindle may be seen to extend from side to side, and this line repre-

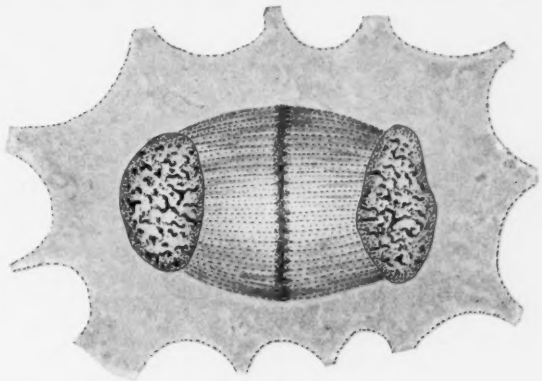


Fig. 33.
An end-stage from the early endosperm of Caltha showing formation of the cell-plate previous to any cell-formation.

sents in optical section the path along which the cell-plate will form. (See Figs. 28 and 29.)

A later stage will show faint specks arranged in a row along the transverse line, and these in a short time fuse so as to form a continuous line across the cell. (See Fig. 31.) This is the rudimentary cell-wall, and as shown by its re-action with Schultze's solution is composed of chemically pure cellulose (probably pectose).

The formation of the cell-plate from a chemical point of view has been the subject of much investigation, and

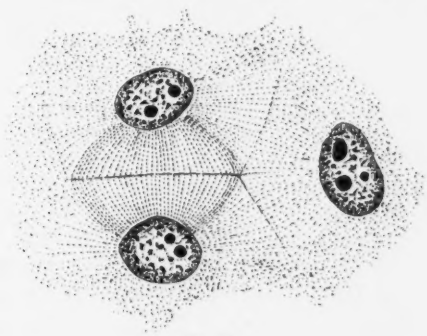


Fig. 34.
The first formation of cells in the early endosperm of Caltha. The spindle-fibres persist and form cytoplasmic bridles.

it has been shown that it is an instance of the almost direct production of cellulose from protoplasm by the splitting off of the nitrogenous moiety of the proteid molecule; it shows us, in fact, that at least in these later stages the substance of the amphiaster is not far removed in constitution from the ectoplasm of the main cytoplasmic mass.

I have been able in the case of Caltha endosperm to obtain several preparations intermediate in time to the formation of free nuclei and the production of cells

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with definite walls. (See Fig. 33.) In these cases a cell-plate was observed in the spindle, but there was no extension of this into the surrounding cytoplasm of the embryo-sac, and consequently no sub-division of the protoplasm into separate cells. Shortly after this definite cells are formed, and the fibrils of the spindles in these are seen to form later the cytoplasmic bridles of the adjacent cells. (See Fig. 34.) A still later stage shows these fibrils persisting as well-marked inter-cytoplasmic connecting threads between adjacent cells. (See Fig. 35.)

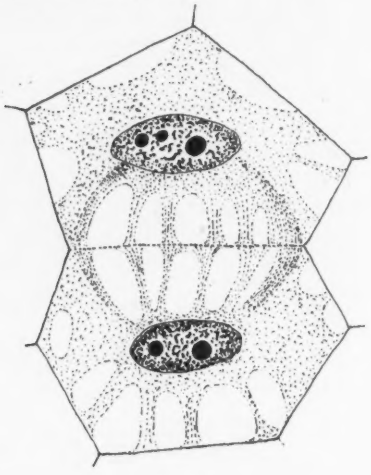

Fig. 35A.

Cells from the late endosperm of Caltha showing persistence of the cytoplasmic bridles of Fig. 34 as intercommunicating fibrils of cytoplasm.

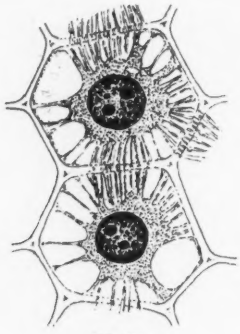

Fig. 35B.

Older cells of Caltha endosperm.

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Chemistry of the Sun and Stars.

By F. W. HENKEL, B.A., F.R.A.S.

JUST fifty years ago, in 1859, the discoveries of Kirchhoff and Bunsen laid the foundations of the science of Stellar Chemistry. Only a few years before that time the opinion had been confidently expressed that "Astronomy has now reached a point where no fresh discoveries of importance, no new principles, are likely to be applied, all that can be expected is that improvements in methods of calculation, in details of observation, and such matters, may be made." Yet at that time Spectrum analysis was unknown, Photography was in its infancy and had been scarcely applied at all to the science, and, consequently, the vast changes which these two methods would produce could not be foreseen by any prophet. In 1859 Astronomy was purely a branch of "Celestial Mechanics." The motions of the planets were known with minute precision, some of the comets had had their orbits calculated and their returns predicted with accuracy, the law of gravitation had been applied with some success to the phenomena of binary and multiple stars, and the sun's motion in space with its probable direction and speed had been ascertained. Laplace's "Nebular hypothesis," with but few modifications, held the field as a reasonable cosmogony accounting for the origin of the present state of our system, the periodicity of sunspots and their connection with terrestrial Magnetism was known, careful and accurate drawings of the visible surface of the moon had been made, and something was known as to the more obvious details to be seen on the planets Mars, Jupiter, and Saturn. Nothing at all was known, however, as to the nature of the materials composing even the nearest of the heavenly bodies, nor could any inference of value be drawn as to the physical conditions, surface temperature, possibilities for life, etc., upon any of these bodies. The mysterious cloud-like bodies known as "nebulæ," faintly luminous but gigantic objects, were generally supposed to be distant clusters, not unlike the Milky Way, which further increase of telescopic power would resolve into separate stars, though Sir W. Herschel had with marvellous intuition formed truer ideas as to their real nature.

The telescope had revealed the existence of countless stars exceeding manifold in number, those visible to the unaided eye, and every increase in optical perfection had brought increased numbers of stars visible, clusters had been resolved into separate stars, and ill-defined objects had been rendered definite. Yet it was reserved for Photography to show that there exist countless dark or faintly luminous objects, quite invisible in most cases to the eye when observing through the best telescope, their light even when collected by the largest mirrors or lenses being too faint to be perceptible, but yet producing by its cumulative effect sensible impressions on the photographic plate. The number of these dark or faintly luminous objects probably far exceeds that of the luminous stars.

By means of photography the whole of the sky, including stars down to the 13th magnitude, is being charted with an accuracy not much inferior to that of meridian circle observations, and this work (though delays have occurred in some quarters), the "Astrographic Catalogue," is being completed, some parts having been already published. It is hoped by repeating this work later on, and by comparison of earlier and later photographs of the same regions of the sky, to discover all kinds of change in position, bright-

ness, etc., on a scale and with a completeness exceeding anything hitherto attempted, and to do thoroughly for the whole sky what has only been imperfectly done for selected regions. Already some results have been obtained. New and hitherto unsuspected variable stars, stars of considerable proper motion, have been detected by comparison of earlier and more recent photographs.

Photography has been applied to the delineation of the details of the moon's surface. The earliest photographs were taken nearly sixty years ago by Bond and De La Rue, using the daguerreotype process; later work by Dr. Henry Draper, and within the last ten years or so the splendid work of the Lick Observatory and that of Messrs. Loewy and Puiseaux at Paris, on a scale far larger and more accurate than that of any drawings previously made, has revealed a wealth of details on the surface of our satellite. The planets, too, have also been photographed, but as yet the results scarcely come up to the best hand drawings, though the most recent photographs of Mars and Jupiter fall little short in this respect of the careful delineations by Green, Dawes, and others. The delicate details of the solar corona, seen only at the rare moments of total eclipse, and the features of nebulæ are especially well shown in photographs. Whilst drawings made by different observers at the same time with instruments not very dissimilar often differ in the most remarkable and unexpected way, on the other hand, photographs show a very satisfactory agreement, so that there can be no doubt that in such cases the latter are to be preferred. Regions of the sky devoid of stars as seen by the eye through the telescope have been shown by the photograph to be full of nebulous matter. For instance, the well-known Pleiades group, "the seven stars" of the ancient mariners, whose number is increased to several hundreds when observed by a powerful telescope, was found many years ago to have some nebulosity near the star Merope, one of its brighter members, but photographs have more recently shown that the whole space occupied by the group is full of "wisps of nebulosity," streaks and streamers of matter emitting light of a character scarcely, if at all, impressing the eye, but producing impression on the photographic plate. "The eye," says Professor Young, "cannot see the nebula with the same telescope which is able to photograph it strongly." The spiral nature of many of the nebulæ has also been detected by means of photographs, though this was unsuspected previously.

Yet it is, perhaps, even more to spectroscopy than to photography that the more remarkable of the recent advances in astronomy are due. More than 200 years ago Newton showed that when the light of the sun (or other white light) is passed through a triangular prism of glass it is not only refracted or changed in direction, but split up into different colours known as the "colours of the rainbow." When this light, before entering the prism, comes from a narrow aperture (or slit) the colours after emergence from the prism are well separated and fairly distinct, and shade by insensible gradations from red, orange, yellow to green, blue and violet. White light being made up of all these colours, which are differently altered in direction after emergence (refracted), the result is that the line of white light becomes a coloured band. To each special shade of colour corresponds a definite position in the spectrum. The electric light or (less satisfactorily) a gas light forms a continuous spectrum, the series of tints being unbroken from red to violet. If, however, we take the spectrum of sunlight we find that, though it is apparently continuous, yet when carefully examined there are a number of more or less dark lines or narrow gaps in it. These "dark, fixed lines" were discovered by Wollaston and Frauenhofer early in the 19th century, and the latter gave the letters A, B, C, D, E, F, G, H to some of the more prominent of these lines. They are, accordingly, known by the name of Frauenhofer lines, but their true nature remained quite unknown for half a century. An incandescent gas, such as hydrogen under low pressure, sodium vapour, etc., gives a spectrum, not continuous, but consisting of one or more bright lines, with intervening dark spaces.

Thus sodium, whose flame has a characteristic yellow tint, when examined by a spectroscope is seen to give a spectrum of two very near yellow lines (D_1, D_2) with some very much fainter ones only visible when high dispersion is used. It was noticed by Stokes and others that the position of these yellow lines (D) corresponded precisely with that of two *dark* lines in the spectrum of the sun (and of some of the stars also), and speculation was rife as to the connection between these phenomena. It was, however, the discovery of Kirchhoff and Bunsen in 1859 that, by placing a comparatively cool vapour between the eye and an incandescent body (electric lamp) giving a continuous spectrum, the spectrum will be no longer continuous, but will be crossed by dark lines, like the solar spectrum. By comparing the dark lines of absorption with the bright lines emitted by the same substances when incandescent they arrived at the fundamental principle—"Every gas when cool absorbs the same kind of radiation as it emits when incandescent." Thus sodium vapour possesses the power of absorbing yellow light of the same kind that it emits, and, consequently, the dark lines (D) in the solar spectrum are due to the absorption (somewhere between us and the solar light giving "photosphere") produced by sodium vapour, less luminous than the general body of the sun.

Solids, liquids, and highly compressed gases, when incandescent, produce continuous spectra, giving light of all degrees of refrangibility from infra-red to ultra-violet. Incandescent gases under low pressure give spectra consisting of only a few bright lines. When we have a nearly continuous spectrum crossed by a number of dark lines we have an incandescent body surrounded by an atmosphere of cooler gases. By comparing the positions of these dark lines with those of the bright lines we can produce, by rendering incandescent various of the known elements, we can determine what substances are contained in this atmosphere. By such means it was soon ascertained that not only is sodium present in the sun, but also iron, hydrogen, calcium, magnesium, potassium, and many other well-known elements. The stars in like manner were found to give indications of the existence of these and other elements in their atmospheres, as indicated by the absorption lines. Maps of the solar and stellar spectra have been published by various observers, Thalen, Angström, and others; of late years photographs or "spectrograms" have been made. The great map of Rowland contains thousands of lines, many of which, however, have not been yet identified. Over 1,000 lines are due to iron alone.

Though, as we have said, the different elements have been detected as existing in the solar and stellar atmospheres, by the correspondence in position of their dark lines with bright lines given by the elements under examination in terrestrial laboratories, yet this correspondence is not complete in every detail. Many substances give different spectra at different temperatures, and under different conditions as to pressure, etc., and lines sharp and distinct in one case become faint

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and blurred in another. Some of the lines due to an element are wanting in the spectra of the sun and stars, whilst other elements seem to be absent altogether. Thus on the sun, chlorine, bromine, sulphur, oxygen (?), and silicon have not yet been detected, and many of the lines of the solar spectrum have not yet been matched. Sir Norman Lockyer and others are, accordingly, of opinion that these missing substances are not really elements, but are decomposed by the great heat existing at the sun and resolved into simpler constituents, producing the unknown lines. Since it is supposed that the dark lines are due to absorption, by relatively cool vapours, of the light coming from the solar "photosphere," if by any means the latter can be cut off we might expect to see a spectrum of bright lines due to the vapours alone, without the bright background.

This has been actually observed by the late Dr. Young and others. On the occasion of a solar eclipse at the moment when the sun's disc is completely obscured and the sun's "atmosphere" is still visible, if the spectroscope be adjusted to view this, the ordinarily *dark* lines of the solar spectrum will be seen for a few seconds *bright* till they disappear, being covered by the moon's advancing limb. This has been seen on various occasions, and shows that the dark lines are produced by a thin layer close to the solar photosphere of not more than about 500 miles in thickness. The sunspots examined by the spectroscope give a spectra not unlike that of the general solar surface, but having some of the lines widened, others thinner than usual. We frequently find, too, the hydrogen lines are bright and not dark, "reversals," and broken lines are of frequent occurrence, which indicate rapid motions of matter towards or from us. Sometimes a velocity of as much as three hundred miles per second has been noticed. By a principle, incorrectly known as Doppler's, the approach of a body which is in vibration will increase the number of waves received from it in a given time, and the wave-length will, consequently, be shortened, whilst recess will produce the opposite effect. Light being a wave motion, the shorter waves will be lengthened by recess and made still shorter by approach, just as the pitch of a note is raised by approach of a sounding body and lowered by its recess. Since the spectrum is practically continuous there is no apparent change of colour, all that is noticed is a slight shift of the lines of the spectrum towards the blue or towards the red end, according as the motion is one of approach or recess. Since, however, the velocity of light, 186,000 miles per second, is enormously great as compared even with solar and stellar motions, the effect produced is very small, but it can be observed, and in this way cyclonic motions of alternate approach and recess have been measured, as also the rate of the sun's rotation on its axis has been determined by the displacement of the Frauenhofer lines in light observed near the right and left hand limbs, one coming forward whilst the other recedes from us. Sir W. Huggins and others have also measured stellar velocities of approach or recess (in the line of sight) varying from 5 to 30 miles per second. The orbital motion of the well-known variable star Algol has been measured in this way by Vogel and other observers, and the class of "spectroscopic binaries" shown to be such by the relative shift of the spectral lines due to the two members of a system was detected.

Suppose a binary star the components of which are too close together to be separately visible in any telescope. Examined by the spectroscope at a time when one member of the system is moving towards us and the other away from us, the spectral lines of this apparently single star will appear *double*, the lines made by one component being displaced towards the blue end of the spectrum, those formed by the other towards the red end. After a time the lines will close up and appear single, then they will again separate, this time in the opposite direction, then again close up, and so on. Thus the period of revolution may be ascertained by observing these changes of appearance. In this way the bright star Capella has been shown to be composed of two stars of distinct types, the spectrum of one component being remarkably like that of the sun, that of the other entirely different, the period of revolution being about 104 days.

Since that time, with the 28-in. telescope of Greenwich, observers have been able to detect the duplicity of the star, and to form a rough estimate of the distance of the components apart, less than $\frac{1}{10}$ of a second of arc. By means of the spectroscope, too, the chromosphere, or coloured outer portion of the sun, visible to the eye only at the time of eclipse, may be studied at other times also. The reason why it is not ordinarily visible is on account of the brightness of the general body of the sun and the illumination of our own atmosphere. If, however, we place a spectroscope with its slit tangential to the sun, we obtain two spectra superposed on one another, the spectrum due to the general sunlight and that due to the chromosphere and its prominences. The former is a nearly continuous spectrum, the latter consists of a few bright lines. If we use a number of prisms, or otherwise increase the dispersive power of the spectroscope, we spread out and greatly enfeeble the luminosity of the continuous spectrum, but do not weaken the bright lines, we merely set them further apart. By thus gradually weakening the background we can make the bright lines due to the prominences visible, and in this way views of the details of these remarkable objects in different coloured light may be obtained. Thus it has been ascertained that there are, roughly, two different kinds of these prominences, the *quiescent* or diffused and the *eruptive* or metallic. The former are of immense dimensions, often 60,000 miles high and of corresponding length, mainly composed of hydrogen, and remain for days without change of form. The latter, on the contrary, are not usually so large, but are continually varying in size and shape, sometimes like flames or spikes, at others of different "fantastic shapes," very brilliant, and associated with active sunspots. They change rapidly in size and shape, and move at times with velocities of from 200 to 300 miles per second, as is shown by distortions and bendings of the spectral lines. So far little is known as to the nature of the corona or "glory" seen round the sun at the time of a total eclipse, which extends sometimes more than a million miles from its surface, but the spectroscope has shown the existence of new and unknown elements in it, to one of which the name of "coronium" has been given. Helium, also found existing in the solar chromosphere before its discovery by Ramsay in the mineral "cleveite," and hydrogen, have been detected in the coronal spectrum, but part of its light seems due to reflection from solid particles. Since as yet no method has been discovered for observing or photographing the corona, save at the rare occurrences of a total eclipse of the sun, only about two hours or so in all in a century, it is, perhaps, not surprising that our knowledge of its nature is limited.

The application of spectrum analysis to the planets has shown that these bodies, though mainly shining by reflected light from the sun, possess atmospheres producing absorption bands in the spectra given by them. The existence of water vapour is nearly certain in the case of Venus and Mars, and probable in that of

Mercury. Jupiter and Saturn, on the other hand, give spectra with no marked absorption bands, but there are some shadings in the red and orange part of their length. The light of these planets seems to come mainly from their upper surfaces without having penetrated to any depth. Uranus and Neptune, however, seem to possess fairly extensive atmospheres producing conspicuous dark bands, the nature of the substance giving these being as yet unknown.

The comets for the most part give faint continuous spectra, due probably to reflected sunlight, generally overlaid by three bright bands, one in the yellow, the second in the green, and the third in the blue. Occasionally a fourth band in the violet is seen. This spectrum is so nearly like that given by the blue flame of a Bunsen burner consuming coal gas that it is universally known as the "hydro-carbon" spectrum. When a comet approaches the sun considerable changes occur in the spectrum, metallic lines, sodium, magnesium, etc., are seen in addition to the hydro-carbon bands. The great comet of 1882 gave evidence of the existence of iron within its substance, and from the known identity of comets and meteor streams we should expect evidence of the existence of metallic substances of this kind in comets generally.

Though a comet gives a spectrum mainly showing the presence of hydro-carbons we must not suppose that these substances comprise the greater part of its mass. "The gaseous portion," says Professor Young, "is probably only a small percentage of the whole quantity of matter contained in it."

The earliest observations of the spectra of the stars were made by Frauenhofer, using a prism in front of the object-glass of a small telescope and observing the stars through this, with a cylindrical lens to widen the size of the spectrum seen. He thus detected the presence of several of the lines seen in the solar spectrum. Capella and Pollux, Castor and Sirius, all gave the D line, though he did not know that this indicated the presence of sodium.

The late Father Secchi examined four thousand stars and roughly divided them into four principal classes. The first class comprised the white or bluish white stars and was the largest, containing more than half of all the stars examined by him. The hydrogen lines were very strong and pronounced, other lines faint or absent. The K line, which is prominent in the solar spectrum, is scarcely visible in most of these stars and is in some cases altogether wanting.

To this class belong Sirius, Vega, and Altair, and they are generally considered to be amongst the hottest and "youngest" of the stars. The second class is composed of stars with spectra nearly like that of the sun. The H and K lines are both fairly strong; Capella, Pollux, Arcturus, and the sun are good examples. As a connecting link between stars of the first and second classes we have stars like Procyon, which, showing the hydrogen lines strongly, also give many other lines between them. These stars are considered to be still intensely hot, but not so hot as those in class I. The third class includes about 500 red and variable stars, giving spectra with *dark* bands instead of lines, shading from the blue towards the red, *i.e.*, more sharply defined at the more refrangible (blue) edge. Some of these stars give bright (instead of dark) hydrogen lines. The well-known variables, Betelgeux and Mira, as also α (Alpha) Herculis, are examples of this class. These stars are probably at a *lower* temperature than the members of the first two classes, but whether they are stars formerly hot, now grown colder, or whether they are younger stars increasing in temperature, we have no certain evidence to show.

The fourth class consists of a very small number of stars, mostly small red stars. These give banded spectra, but the bands, unlike those in the third class of stars, are shaded towards the blue end of the spectrum, being more sharply defined towards the red. A sixth magnitude star in the constellation of Canes Venatici, known as 152 Schjellerup, is the best example of this class, which comprises only about 60 or so of the stars examined by Secchi.

Sir Norman Lockyer, in his Meteoric hypothesis, divides the stars into six classes, according to the nature of their spectra. In the first group radiation lines and flutings are predominant, the radiation being chiefly of hydrogen and magnesium. β Lyræ and γ Cassiopeiæ are examples of this group. The second group "mixed radiation and absorption," radiation due to carbon vapour, absorption produced by magnesium, iron, lead and barium, etc. Mira Ceti is an example of this class. The third group, line absorption predominant, temperature increasing. Alpha Cygni (Deneb) is given as an example. The fourth group comprises the hottest stars, spectra characterised by strong absorption of hydrogen, metallic lines thin and faint. Vega and Sirius belong to this group. The fifth group includes the sun, Capella, Pollux, etc. The lines are narrow and very numerous, line absorption predominant "with decreasing temperature." "The spectrum of the sun can be almost perfectly reproduced by volatilising a mixture of meteorites in the electric arc" (Lockyer, Elementary Astronomy, p. 252). The sixth and last group contains stars of a deep red tint; carbon absorption is predominant. The star "152 Schjellerup" is given as a typical specimen of this class.

It will be seen that some of these groups correspond more or less closely with those of Secchi. Group IV. with Secchi's first class, Group V. with his second, Group II. with the third class, Group VI. with the fourth. Messrs. Wolf and Rayet, of Paris, have added a fifth type to the four classes of Secchi. A number of stars were found by them to possess spectra having a singular mixture of dark bands and bright lines, as though three distinct spectra were combined, one being continuous, the second an absorption spectrum, and the third an emission spectrum as though from glowing gas. Nearly all the stars showing this kind of spectrum are found to be situated near the central line of the Milky Way. Vogel proposed to sub-divide Secchi's types into small sub-types, characterised by special peculiarities in the relative intensities of the hydrogen and metallic lines, and a very minute sub-division has been made by the Harvard observers, whose work was published as part of the "Draper memorial."

It must be mentioned that there are many star spectra which cannot be properly included in any of the classes hitherto mentioned, but have peculiarities of their own. In the main, however, it has been found that the stars are composed of elements similar to those found in our sun and earth. Thus, so far as research has yet gone, we may say that "earth and stars seem to be made of like matter." Helium, first discovered in the solar chromosphere, has been found also existing in small quantities on the earth, but so far the substance giving the D_3 line in the coronal spectrum known as "coronium" has not been identified with any terrestrial element. Hydrogen, found apparently existing in vast quantities on the sun and stars in the free state, is only known to us in combination, whilst oxygen, the most universal terrestrial element, has been very doubtfully identified in the solar spectrum. Different conditions

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of temperature and pressure, we know, enormously modify the spectrum given by the same element, and since we know that very different conditions must prevail amongst the stars it is, perhaps, rather a subject for surprise that we have been able to satisfactorily identify so many of our terrestrial elements as existing elsewhere, than that we have not yet been able to identify all of them. Every year the number of elements discovered as existing on the various stars is increased by fresh discoveries. Within the last few years sulphur has been detected in Rigel (Beta Orionis), tin in Antares (Alpha Scorpii), and titanium and vanadium in the sun.

The application of the spectroscope to the study of the nebulæ has shown that the light of many of these bodies proceeds mainly from faintly luminous gas. This had been previously suspected by Sir William Herschel, but after Lord Rosse's great telescope had "resolved" so many of these bodies into clusters of stars the opinion had arisen that all such were merely far distant clusters, outlying "Universes." Some of the nebulæ give a nearly continuous spectrum unmarked by any lines or bands either bright or dark, and may consist of solid or gaseous matter under pressure; others give a spectrum of six or seven bright lines, three of which are due to hydrogen, another may be due to magnesium vapour, whilst the origin of the rest is unknown. Since these bodies, though so enormous in size, some greatly exceeding in diameter the apparent size of the sun or moon (and, of course, at distances millions of times greater from us), are so faintly luminous as to be visible only in powerful telescopes, their physical condition must be very different from that of anything we have experience of on earth.

In all probability the residual air in the vacuum of an air pump is a *plenum* by comparison. That they are completely transparent through such enormous dimensions shows their extreme tenuity. "Were our solar system placed in the midst of one of them it is probable we should be unable to find any evidence of its existence." Whether such was the original condition from which sun and planets have in the course of ages evolved, or whether the nebulæ are the result of collisions of the "suns," and are the final repositories of the immense amount of energy radiated from luminous bodies into space and apparently lost, we do not know. It has been supposed by various philosophers at different times that there are cycles of growth and of decay in the evolution of the Universe. Nebulæ condense and form suns with their attendant planets and satellites; suns collide with one another and give rise to nebulæ in their turn. Thus the process goes on without beginning or end, either in time or in space.

Star Maps 9, 10.

By MRS. H. PERIAM HAWKINS.

THE series of star maps, commenced some time ago in this magazine, is now in course of completion, No. 9 having appeared in last month's issue, while No. 10 is included in the present number, and No. 11 will, we hope, follow in October. No. 12, comprising the South Polar Regions, has already appeared.

Map 9, including the constellations of Ophiuchus, Libra, and Scorpio, with a considerable portion of Sagittarius and a few of the southern constellations, shows but one star of the 1st magnitude, viz., *a Scorpii*, Antares, the "Rival of Mars" (XVI.^{h} 23^m 26° 18′ south). It is a fine deep red star, and, during the summer months, flashes brightly rather low down in the south. Scorpio occupies a larger space in the heavens than any other of the zodiacal constellations.

Ophiuchus, the "Serpent Bearer," is supposed to be treading upon the head of the scorpion, while he grasps the serpent in both hands.

70 Ophiuchi, a few degrees from the star *Gamma*, is a fine binary, having a period of less than a century.

Lambda Ophiuchi, on the confines of Serpens, is also a binary with a period of about 230 years.

The *Trifid Nebula*, 20M in Sagittarius, is believed to be a remarkable illustration of the possible breaking up of a nebula by the drifting of a star through its centre.

Map 10, which includes the constellations of Lyra, Cygnus, and Aquila, comprises one of the richest portions of the Milky Way.

Lyra is usually represented as an eagle with a lyre hanging from its neck. Its principal star, *Vega*, the "Swooping Eagle," is of a lovely pale sapphire tint, but, perhaps, the chief interest of this beautiful star lies in the fact that it is believed to mark, within about four degrees, the "Apex of the Sun's Way," that point in the heavens towards which the sun is rushing through space, with all the members of his family, at the rate of about a million miles a day, or 12½ miles a second.

Beta Lyræ is a well-known variable star. Its nature was discovered by the deaf and dumb astronomer, Goodricke, in 1784, a year after his discovery of Algol, the variable star of Perseus.

The fluctuations in the light of Beta Lyræ are owing, it is believed, to the revolution in small orbits of two bright stars around each other.

Within a few degrees to the left of this star is the *Ring Nebula*, 57M, which is the only annular nebula that can be seen with a small telescope.

The constellation of *Cygnus*, "the Swan," is also known as the "Northern Cross."

The star *Deneb*, or *Deneb Adige*, the "Tail of the Hen," also called *Arided*, forms the head of the cross. *Albireo* (Beta Cygni) is the foot, while the stars which represent the outspread wings of the bird, viz., Delta, Gamma, and Epsilon, form the transverse piece of the cross.

Beta Cygni is a beautiful double star, the one bright yellow, and the other sapphire blue.

61 Cygni is the star nearest to the earth, at present known, in the northern hemisphere. Its light, however, takes about 7¼ years to reach us, travelling at the rate of 186,330 miles a second.

To the south of the small constellation of *Vulpecula*, "the Fox," is the famous *Dumb-bell Nebula*, 27M. As observed with a small telescope it bears a distinct resemblance to a dumb-bell, the nebulous mass being attenuated in the middle and broadened at either end.

The little constellation of *Sagitta*, "the Arrow," is full of interest for the observer with its variously coloured stars.

The star *Gamma*, in the *Dolphin*, is a binary composed of a bright yellow star and a pale blue companion.

The constellation of *Aquila*, "the Eagle," with its three chief stars, *Altair*, "the Soaring Eagle," *Tarazed*, "the Robber," and *Alshain*, "the White Falcon," occupies a rich field in the Milky Way. To the south of Alshain is the variable star *Eta*, the periodical fluctuations of which, occurring during the short period of a week and four hours, may be well observed with the aid of an opera-glass.

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MAP No. 10.

BRIGHTNESS.

- 1st Mag.
- 2nd ,,
- 3rd ,,
- 4th ,,
- 5th ,,
- 6th ,,
- Variable.
- Nebula.

MAP 10.

Lyra, Cygnus, Aquila.

Some Brilliant Meteors—August, 1909.

By IRENE E. TOYE WARNER.

THE famous Perseid Shower was well observed this year, owing, perhaps, to the warm weather and fairly clear skies on the nights of August 10, 11, and 12. On August 10 Mr. W. F. Denning watched the sky for $1\frac{3}{4}$ hours, but only 19 meteors were seen, 12 of which were Perseids. At Bristol, on the evening of the 11th, the best weather prevailed, and in a watch of only one hour and 37 minutes—from 10 hrs. to 11 hrs. 37 m.—I counted over 60 meteors, 55 of which were Perseids. Ten out of this number were certainly well above the 1st magnitude in brilliancy.

The first meteor, seen at 9 hrs. 57 m., was a fine Perseid brighter than Jupiter and of much the same colour. It traversed a long path in a western direction over the zenith from the radiant, the approximate position being 150° + 75° to 195° + 40°. It was also seen by Mr. T. K. Jenkins at Blaina, and from the double observations Mr. W. F. Denning estimated the height above the earth, at the commencement of its visible path, as 103 miles over Denbigh, N. Wales, to 48 miles over Pembroke at the end, the length of its course being 110 miles and its velocity about 32 miles per second. Another meteor equalling Jupiter appeared almost simultaneously; it also was trained and long-pathed.

Numerous small members of the swarm flashed like rockets in all directions from the radiant. It was quite impossible to record every individual, as several would come at the same moment and also with tremendous velocity which made them exceedingly difficult to register satisfactorily. At 10 hrs. 40 m. another meteor as bright as Jupiter displayed a lovely blue train and streak, from 45° + 80° to 195° + 75°. This was followed at 10 hrs. 45 m. by a bluish one of the 1st magnitude, having a long train; position was 10° + 30° to 1° + 10°; and another at 10 hrs. 48 m. from 2° + 59° to 330° + 50°; the latter was pale yellow and had a train and streak.

There was a slight interval until 11 hrs. 8 m., when the sky was illuminated by a slow blue-yellow meteor rivalling Jupiter in brilliancy and having a train of "sparks" and a fine streak; visible path from 5° + 25° to 353° ± 0°. Perhaps the prettiest meteor seen during the evening was one which fell slowly at 11 hrs. 18 m. from 60° + 58° to 90° + 48°. It was exactly like a large blue Chinese light with a small train, and it equalled Vega in brilliancy. The last, observed at 11 hrs. 37 m., was 1st magnitude blue colour with both train and streak, its approximate path being from 347° + 27° to 323° + 7°.

Mr. J. H. Elgie, of Leeds, estimated that he saw about 100 meteors on August 11 between 11 and 12 p.m. He appears to have looked towards Corona, whilst I kept my attention fixed on the radiant and the Square of Pegasus, in the hopes of seeing a stationary meteor. Mr. J. Clark Jefferson, of Moor Allerton, and three other observers counted 105 meteors on the 11th between 11 hrs. and 11 hrs. 45 m. On the same evening Mr. Denning observed for $2\frac{3}{4}$ hours and saw 73 meteors, nearly all being Perseids from 46° + 58°.

On August 12 the meteors seem to have been more brilliant, but not so numerous, and fog prevented a long watch in this part of the country. In half-an-hour, from 10 hrs. 30 m. to 11 hrs., I saw nine meteors, three of which were not Perseids. One at 10 hrs. 35 m. was 1st magnitude and had a train and streak; path from 345° + 30° to 325° + 12°. At 10 hrs. 45 m. I was fortunate enough to observe a very interesting and beautiful meteor with an enormously long path from about 360° + 42° to 327° + 10°. It equalled, if not surpassed, Jupiter in brilliancy, and had a long train and bright streak which remained visible for about three seconds; its velocity was moderate. At 11 hrs. fog prevented observations.

Mr. W. F. Denning counted 65 meteors on the 12th between 9 hrs. and 12 hrs. 52 m. He says that relatively to the total number seen he has never observed such an abundance of fine flashing meteors. The most brilliant Perseid of the shower was seen on August 12 at 9 hrs. 42 m. It lit up the sky like lightning and left a streak which lasted for several minutes. Mr. Denning places its radiant at about 47° + 58°, and says it passed over the earth at a point 10 miles W. of Ipswich to 15 miles E. of Croydon. Its height was from 87 to 53 miles and length of path 68 miles, which it traversed with a velocity of about 35 miles per second.

Observational results varied greatly at different stations, and quite naturally so, since atmospheric conditions are rarely the same, the "seeing" capacity of observers is often widely dissimilar, and some situations are much more open than others. Mr. Denning tells me that he regards the display of 1909 as a tolerably productive one which will certainly afford some useful data. The point of emanation near Eta Persei has often been determined, and mere repetitions in deriving it from new materials are not of much consequence; but it would, he thinks, be interesting if in coming years observers banded together and watched Perseid radiation very closely from about July 25 to August 15, as the centre takes up a new position from night to night and it may be desirable to test the ephemeris.

When the Perseid radiant was low in the E.N.E. the meteors exhibited long flights and were moderately slow in apparent velocity, but later in the night, when the stars of Perseus were higher in the sky, the meteors were much shorter and traversed very swift, short, diving tracks. No doubt, says Mr. Denning, the velocity of the objects having nearly horizontal paths is moderated by the earth's attraction and by the dense atmospheric layers encountered during their long flights.

The maximum of the late display occurred on the night of August 11, but there were many meteors on the 12th and a fair number on the 10th.

A MACHINE which will lay a railway line, carrying the sleepers, ties, and rails much in the same way that a bicycle chain is carried over the cog-wheel, and depositing them as it moves, was recently described in our columns. The invention, we need hardly say, is American, and it is now to be supplemented by another, which will prepare and raise the embankments or tracks on which the line is to be laid. Evidently a railway-line laying machine would not suffice unto itself unless the new country in which the line is laid has been prepared beforehand, or is so flat and even as to seem designed by Providence for man's greatest instrument of civilisation. The purpose of the new machine is "to prepare and ballast track, doing the work of the lifting-jacks and gangs of shovellers and tampers. It is designed to build embankments without the use of trestles." A description of it here would involve too many technicalities; but it may be briefly outlined as a kind of double crane joined to steam shovels. The cranes lay the section of rail, the shovels dig beneath it, and, being arranged to go out $7\frac{1}{2}$ ft. beyond the ends of the ties and 4 ft. below them by the radial and vertical motions of the arms, are able to dig out or hoist up and pack down a low embankment sustaining the rails. The shovels can slam down the earth as well as dig it up; and the optimistic inventors see in their machine a device which, worked by five men, will do the work of a hundred navvies, with shovellers, tampers, and jacks.

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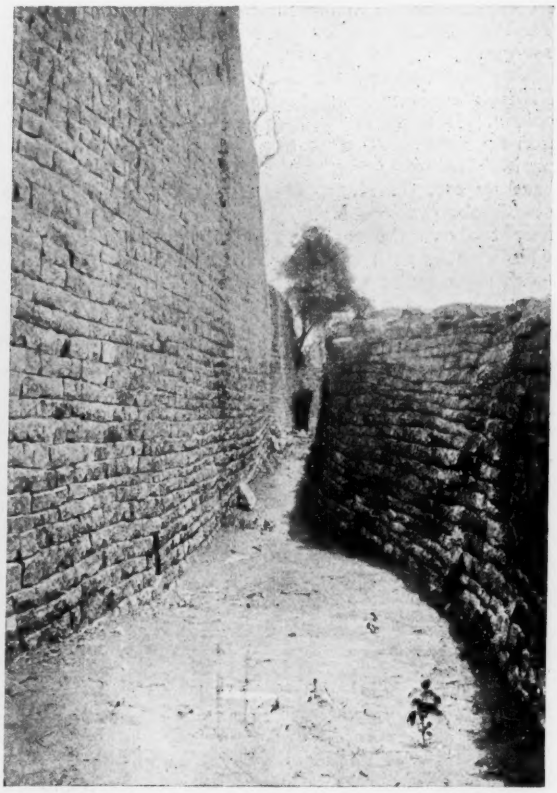
The Antiquity of Rhodesia.*
Mr. R. N. Hall and Zimbabwe.

IN the main the outlines of the controversy between Mr. R. N. Hall and Dr. McIver as to age of the stone buildings of South Africa are well known. The temple of Great Zimbabwe, in Mashonaland, first made familiar by Mr. Theodore Bent, is an imposing edifice of stone. It has no great architectural pretensions, nothing like the temples which the Egyptians built in North Africa when the Israelites were but a nomad tribe of Arabia and the Bible not yet written; nothing to compare with

Conical Tower, Stone Pulpit-Platform, and Circular Cement Platform with Monoliths.
After the excavations by the author (1901).
The Temple, Zimbabwe.

the remains of architectural achievement in Asia and the Americas, which are many centuries old. But it is built soundly and solidly; the masonry is good; it was laid down with some clear design and for some specific purpose; and the design and the purpose are not explicable by any relic of custom or worship in South Africa to-day. In the ruins have been found ornaments and certain primitive sculptures, which also seem remote from any analogues among the savage South African races, as they appear now; and, perhaps, one of the clearest distinctions between the building and design of the Zimbabwe Temple—for that is what it is supposed to be—is that it possesses an elaborate system of drainage.

It can hardly be wondered at that Mr. Bent, Mr. R. N. Hall, and others who first examined this extremely curious relic of a past age came to the conclusion that it had been erected by a people altogether removed in customs, culture, and civilisation from the Mashonas, Zulus, and other races of nineteenth century South Africa. If the legends and traditions of the Kaffir peoples are too little known, too inchoate, too inarticulate, or too little understood to enable one to say positively whether an ancient people, now without descendants or representatives, ever dwelt in South Africa, yet among other peoples whose records are better preserved the legend of a land of Ophir, deep in the recesses of Africa, from which gold, and ivory, and



Original Wall. **Exterior (North) of Temple.** **Later Wall.**

jewels come, is distinct if not definite. To this nebulous tradition it seemed to Mr. Theodore Bent and Dr. Carl Peters, and finally to Mr. R. N. Hall, that the ruins of Zimbabwe gave outline and furnished a proof of its reality. The hypothesis framed by Mr. Hall in his earlier books ("The Great Zimbabwe, Mashonaland," for example) was that Rhodesia was, many centuries ago, exploited by Arabs, Persians, and Indians, as the relics of remarkably extensive ancient gold mining operations show. These operations represent, according to some authorities, the withdrawal of very many millions of pounds' worth of gold from the rock strata. The peoples who thus colonised this region—colonising it not in the modern sense, but establishing distant settlements there, which were partly peopled by slaves and partly by imported labourers—built there and taught their dependents to build. Thus the mining operations resulted in the importation and display of the art of building in dressed stone, and of the ceremonial of which the Zimbabwe

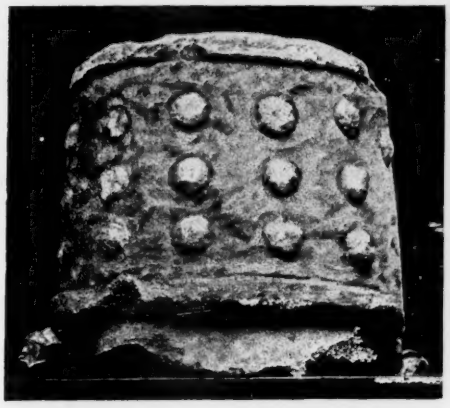
* "Pre-historic Rhodesia." An examination of the historical, ethnological, and archæological evidences as to the age and origin of the rock mines and stone buildings. By R. N. Hall (Fisher Unwin), 12s. 6d. net.

Temple is a remaining token. After the display of this Asiatic culture on a colossal scale it met with a sudden catastrophe, either caused by loss of the sustaining foreign influence, or by the arrival of hordes of Bantu barbarians from the north (or, possibly, by the encroachment of some such disease as sleeping sickness). The Bantu invaders, if such they were, knew nothing of the value of gold, or of building in stone, or of the Zimbabwe ceremonial, and the mining and building operations came to an end. Left entirely to their own

Cylinder with Rosettes found at Zimbabwe.
The hole was cut completely through the stone before the rosettes were carved.

resources, the Bantu copied in very crude form the Zimbabwe style of building, washed soil and river sand for gold instead of mining on the rock for depth, until both in building and gold extraction they became degraded to the level visible during the last two or three centuries.

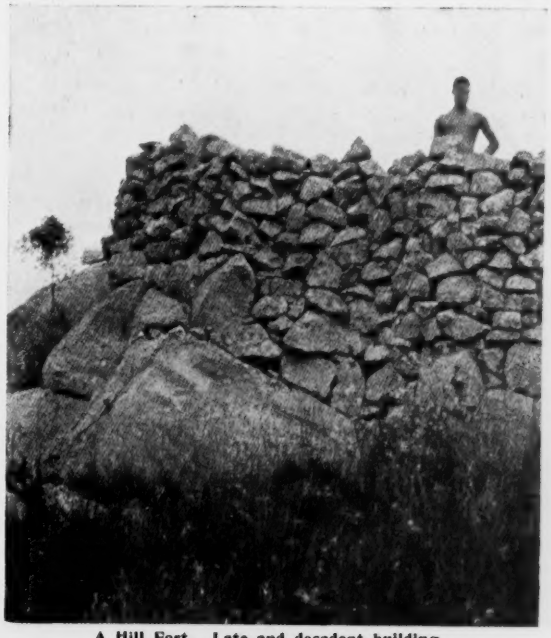
The other point of view is that of Professor McIver, who examined both the ruins and the hypothesis. In part of the ruins Professor McIver found Nankin china of a date only a few centuries old, and he found it in



Cylinder with Rosettes found in Phœnician Temple of Paphos, in Cyprus.

such a position and in such circumstances that he became convinced that it was there previous to the erection of the Temple of which the ruins now remain. The architecture and structure of the Temple he assigned to no earlier race than the Bantu. He assumed that the Bantus, in a state of progressive degradation, had forgotten the art of building in stone, and that the Zimbabwe Temple and its analogues are merely sublimated translations in stone of the principles of construction of a Kaffir hut. For the relics, such as carved birds and other ornaments which were found at Zimbabwe, Professor McIver found parallels in the carved totems with which Bantu children still play. The Temple, as a whole, he regarded as merely a glorified Kaffir kraal, and while he could find no evidence in legend or tradition of a pre-historic habitation of Rhodesia of an alien race, he believed that historic evidence of Portuguese documents pointed all the other way; that is to say, to the fact that the Zimbabwe Temple and other rock buildings of the region were constructed and used by the race tenanting Rhodesia a few centuries ago.

Professor McIver's conclusions, ably and scientifically stated, made a profound impression when he brought them forward in 1905. In the book before us Mr. R. N. Hall writes the first instalment of a reply to them in detail. It is not possible to do justice to all Mr. Hall's arguments in a short summary of them, and for that the reader must be referred to his very interest-



A Hill Fort. Late and decadent building.
Kaffirisation reached.

ing book, to the publishers of which we are indebted for permission to reproduce the accompanying photographs. But the strongest point Mr. Hall makes seems to us to be in his production of evidence that the buildings of Rhodesia are not all of the same age. They do not thus show a mere decline in building ability, but totally different stages of masonic and architectural achievement. The stages, as represented by the results are as follows :—

(*a*) The original Zimbabwe type; finest construction; granite blocks dressed by chisels and hammers; elaborate drainage system; evidences of nature worship, birds on beams, conical tower, ornate phalli, cylinder or *linga*, sun images, monoliths; foreign decorative designs; oldest class of relics, such as *astragali* ingot mould; great wealth in chaste gold ornaments; no woodwork left.

(*b*) N'Natali, Dhlo-dhlo and Khami type, evidencing a decadence in construction and relic from the Zimbabwe type; built on terrace system; no phallic worship;

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no birds, phalli, or tower; no old Zimbabwe relic; introduction of later angular features of construction; no drainage system; only Bantu relics of a superior make to those of to-day; poorer building construction; Kaffirisation in construction reached.

(*c*) The Inyanga type: poor construction; no courses; stones undressed and all sizes and shapes mixed; shell faces to walls; interior portions of walls filled in with rubble; monoliths, no phallic emblems; no old relics; only old Bantu articles; do not contain a grain of gold; evidences in shelter-pits and aqueducts of old Zaide Arab influence of the tenth and eleventh centuries.

Ruin of later and decadent period in which Nankin China was found.

(*d*) Bantu type of building: all over Rhodesia, but mainly on summits of hills; mere rough barricades of rudely piled-up stones; some not 200 years old, a few even later; articles of Kaffir make resembling those made to-day; the builders being old Ma-Karanga, Leghoya and Ma-Lemba.

The argument will be perceived from this arrangement, and it is that after the original people had gone, at some indefinite date before 915 A.D., the people who were left tried at first to build in imitation. But these people, in their turn, were swept away, just as the bulk of the relics were swept away—unless they were of such permanence as Zimbabwe itself—and that, finally, the natives tried to reproduce with less and less fidelity and success the old buildings. Even that art became lost, because the Bantus were incapable of learning a civilisation which had always been far beyond them. Quite apart from the question of the argument, the disclosure by Mr. Hall of the great numbers of Rhodesian ancient stone buildings is of great value and interest.

Sir J. J. Thomson on Molecular Electricity.

British Association Meeting at Winnipeg.

THE Seventy-Ninth Meeting of the British Association, which is now in progress at Winnipeg, was formally inaugurated on Wednesday, August 25, by the Presidential Address of Sir J. J. Thomson, F.R.S. The President, in his opening remarks, happily observed that when the Association first met in Canada it became transformed from a British into an Imperial Association of Science. The presence of a number of members of the American Association of Science further lent to it an international aspect. In the earlier part of the Address Sir J. J. Thomson made some trenchant comments on the uselessness of the English scholarship system in encouraging research. The rest of the Address continued as follows:—

IT has usually been the practice of the President of this Association to give some account of the progress made in the last few years in the branch of science which he has the honour to represent.

I propose this evening to follow that precedent and to attempt to give a very short account of some of the more recent developments of physics, and the new conceptions of physical processes to which they have led.

The period which has elapsed since the Association last met in Canada has been one of almost unparalleled activity in many branches of physics, and many new and unsuspected properties of matter and electricity have been discovered. The history of this period affords a remarkable illustration of the effect which may be produced by a single discovery; for it is, I think, to the discovery of the Röntgen rays that we owe the rapidity of the progress which has recently been made in physics. A striking discovery like that of the Röntgen rays acts much like the discovery of gold in a sparsely-populated country; it attracts workers who come in the first place for the gold, but who may find that the country has other products, other charms, perhaps even more valuable than the gold itself. The country in which the gold was discovered in the case of the Röntgen rays was the department of physics dealing with the discharge of electricity through gases, a subject which, almost from the beginning of electrical science, had attracted a few enthusiastic workers, who felt convinced that the key to unlock the secret of electricity was to be found in a vacuum tube. Röntgen, in 1895, showed that when electricity passed through such a tube, the tube emittted rays which could pass through bodies opaque to ordinary light; which could, for example, pass through the flesh of the body and throw a shadow of the bones on a suitable screen. The fascination of this discovery attracted many workers to the subject of the discharge of electricity through gases, and led to great improvements in the instruments used in this type of research. It is not, however, to the power of probing dark places, important though this is, that the influence of Röntgen rays on the progress of science has mainly been due; it is rather because these rays make gases, and, indeed, solids and liquids, through which they pass conductors of electricity. It is true that before the discovery of these rays other methods of making gases conductors were known, but none of these was so convenient for the purposes of accurate measurement.

The study of gases exposed to Röntgen rays has revealed in such gases the presence of particles charged with electricity; some of these particles are charged with positive, others with negative electricity.

The properties of these particles have been investigated; we know the charge they carry, the speed with which they move under an electric force, the rate at which the oppositely charged ones recombine, and these investigations have thrown a new light, not only on electricity, but also on the structure of matter.

We know from these investigations that electricity, like matter, is molecular in structure, that just as a quantity of

hydrogen is a collection of an immense number of small particles called molecules, so a charge of electricity is made up of a great number of small charges, each of a perfectly definite and known amount.

Helmholtz said in 1880 that in his opinion the evidence in favour of the molecular constitution of electricity was even stronger than that in favour of the molecular constitution of matter. How much stronger is that evidence now, when we have measured the charge on the unit and found it to be the same from whatever source the electricity is obtained. Nay, further, the molecular theory of matter is indebted to the molecular theory of electricity for the most accurate determination of its fundamental quantity, the number of molecules in any given quantity of an elementary substance.

The great advantage of the electrical methods for the study of the properties of matter is due to the fact that whenever a particle is electrified it is very easily identified, whereas an uncharged molecule is most elusive; and it is only when these are present in immense numbers that we are able to detect them. A very simple calculation will illustrate the difference in our power of detecting electrified and unelectrified molecules. The smallest quantity of unelectrified matter ever detected is probably that of neon, one of the inert gases of the atmosphere. Professor Strutt has shown that the amount of neon in $\frac{1}{20}$ of a cubic centimetre of the air at ordinary pressures can be detected by the spectroscope; Sir William Ramsay estimates that the neon in the air only amounts to one part of neon in 100,000 parts of air, so that the neon in $\frac{1}{20}$ of a cubic centimetre of air would only occupy at atmospheric pressure a volume of half a millionth of a cubic centimetre. When stated in this form the quantity seems exceedingly small, but in this small volume there are about ten million million molecules. Now the population of the earth is estimated at about fifteen hundred millions, so that the smallest number of molecules of neon we can identify is about 7,000 times the population of the earth. In other words, if we had no better test for the existence of a man than we have for that of an unelectrified molecule we should come to the conclusion that the earth is uninhabited. Contrast this with our power of detecting electrified molecules. We can by the electrical method, even better by the cloud method of C. T. R. Wilson, detect the presence of three or four charged particles in a cubic centimetre. Rutherford has shown that we can detect the presence of a single α particle. Now the α particle is a charged atom of helium; if this atom had been uncharged we should have required more than a million million of them, instead of one, before we should have been able to detect them.

We may, I think, conclude, since electrified particles can be studied with so much greater ease than unelectrified ones, that we shall obtain a knowledge of the ultimate structure of electricity before we arrive at a corresponding degree of certainty with regard to the structure of matter.

We have already made considerable progress in the task of discovering what the structure of electricity is. We have known for some time that of one kind of electricity—the negative—and a very interesting one it is. We know that negative electricity is made up of units all of which are of the same kind; that these units are exceedingly small compared with even the smallest atom, for the mass of the unit is only $\frac{1}{1700}$ part of the mass of an atom of hydrogen; that its radius is only 10^{-13} centimetre, and that these units, "corpuscles" as they have been called, can be obtained from all substances. The size of these corpuscles is on an altogether different scale from that of atoms; the volume of a corpuscle bears to that of the atom about the same relation as that of a speck of dust to the volume of this room. Under suitable conditions they move at enormous speeds which approach in some instances the velocity of light.

The discovery of these corpuscles is an interesting example of the way Nature responds to the demands made upon her by mathematicians. Some years before the discovery of corpuscles it had been shown by a mathematical investigation that the mass of a body must be increased by a charge of electricity. This increase, however, is greater for small bodies than for large ones, and even bodies as small as atoms are hopelessly too large to show any appreciable effect; thus the result seemed entirely academic. After a time corpuscles were discovered, and these are so much smaller than the atom that the increase in mass due to the charge becomes not merely appreciable, but so great that, as the experiments of Kaufmann and Bucherer have shown, the whole of the mass of the corpuscle arises from its charge.

We know a great deal about negative electricity; what do we know about positive electricity? Is positive electricity molecular in structure? Is it made up into units, each unit carrying a charge equal in magnitude though opposite in sign to that carried by a corpuscle? Does, or does not, this unit differ, in size and physical properties, very widely from the corpuscle? We know that by suitable processes we can get corpuscles out of any kind of matter, and that the corpuscles will be the same from whatever source they may be derived. Is a similar thing true for positive electricity? Can we get, for example, a positive unit from oxygen of the same kind as that we get from hydrogen?

For my own part, I think the evidence is in favour of the view that we can, although the nature of the unit of positive electricity makes the proof much more difficult than for the negative unit.

In the first place we find that the positive particles—"canalstrahlen" is their technical name—discovered by our distinguished guest, Dr. Goldstein, which are found when an electric discharge passes through a highly rarefied gas, are, when the pressure is very low, the same, whatever may have been the gas in the vessel to begin with. If we pump out the gas until the pressure is too low to allow the discharge to pass, and then introduce a small quantity of gas and restart the discharge, the positive particles are the same whatever kind of gas may have been introduced.

I have, for example, put into the exhausted vessel oxygen, argon, helium, the vapour of carbon tetrachloride, none of which contain hydrogen, and found the positive particles to be the same as when hydrogen was introduced.

Some experiments made lately by Wellisch, in the Cavendish Laboratory, strongly support the view that there is a definite unit of positive electricity independent of the gas from which it is derived; these experiments were on the velocity with which positive particles move through mixed gases. If we have a mixture of methyl-iodide and hydrogen exposed to Röntgen rays, the effect of the rays on the methyl-iodide is so much greater than on the hydrogen that, even when the mixture contains only a small percentage of methyl-iodide, practically all the electricity comes from this gas, and not from the hydrogen.

Now if the positive particles were merely the residue left when a corpuscle had been abstracted from the methyl-iodide, these particles would have the dimensions of a molecule of methyl-iodide; this is very large and heavy, and would therefore move more slowly through the hydrogen molecules than the positive particles derived from hydrogen itself, which would, on this view, be of the size and weight of the light hydrogen molecules. Wellisch found that the velocities of both the positive and negative particles through the mixture were the same as the velocities through pure hydrogen, although in the one case the ions had originated from methyl-iodide and in the other from hydrogen; a similar result was obtained when carbon tetrachloride, or mercury methyl, was used instead of methyl-iodide. These and similar results lead to the conclusion that the atoms of the different chemical elements contain definite units of positive as well as of negative electricity, and that the positive electricity, like the negative, is molecular in structure.

The investigations made on the unit of positive electricity show that it is of quite a different kind from the unit of negative, the mass of the negative unit is exceedingly small compared with any atom, the only positive units that up to the present have been detected are quite comparable in mass with the mass of an atom of hydrogen; in fact, they seem equal to it. This makes it more difficult to be certain that the unit of positive electricity has been isolated, for we have to be on our guard against its being a much smaller body attached to the hydrogen atoms which happen to be present in the vessel. If the positive units have a much greater mass than the negative ones they ought not to be so easily deflected by magnetic forces when moving at equal speeds; and in general the insensibility of the positive particles to the influence of a magnet is very marked, though there are cases when the positive particles are much more readily deflected, and these have been interpreted as proving the

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existence of positive units comparable in mass with the negative ones. I have found, however, that in these cases the positive particles are moving very slowly, and that the ease with which they are deflected is due to the smallness of the velocity and not to that of the mass. It should, however, be noted that M. Jean Becquerel has observed in the absorption spectra of some minerals, and Professor Wood in the rotation of the plane of polarisation by sodium vapour, effects which could be explained by the presence in the substances of positive units comparable in mass with corpuscles. This, however, is not the only explanation which can be given of these effects, and at present the smallest positive electrified particles of which we have direct experimental evidence have masses comparable with that of an atom of hydrogen.

A knowledge of the mass and size of the two units of electricity, the positive and the negative, would give us the material for constructing what may be called a molecular theory of electricity, and would be a starting-point for a theory of the structure of matter; for the most natural view to take, as a provisional hypothesis, is that matter is just a collection of positive and negative units of electricity, and that the forces which hold atoms and molecules together, the properties which differentiate one kind of matter from another, all have their origin in the electrical forces exerted by positive and negative units of electricity, grouped together in different ways in the atoms of the different elements.

As it would seem that the units of positive and negative electricity are of very different sizes, we must regard matter as a mixture containing systems of very different types, one type corresponding to the small corpuscle, the other to the large positive unit.

Since the energy associated with a given charge is greater the smaller the body on which the charge is concentrated, the energy stored up in the negative corpuscles will be far greater than that stored up by the positive. The amount of energy which is stored up in ordinary matter in the form of the electrostatic potential energy of its corpuscles is, I think, not generally realised. All substances give out corpuscles, so that we may assume that each atom of a substance contains at least one corpuscle. From the size and the charge on the corpuscle, both of which are known, we find that each corpuscle has 8×10^{-7} ergs of energy; this is on the supposition that the usual expressions for the energy of a charged body hold when, as in the case of a corpuscle, the charge is reduced to one unit. Now in one gramme of hydrogen there are about 6×10^{23} atoms, so if there is only one corpuscle in each atom the energy due to the corpuscles in a gramme of hydrogen would be 48×10^{14} ergs, or 11×10^{9} calories. This is more than seven times the heat developed by one gramme of radium, or than that developed by the burning of five tons of coal. Thus we see that even ordinary matter contains enormous stores of energy; this energy is fortunately kept fast bound by the corpuscles; if at any time an appreciable fraction were to get free the earth would explode and become a gaseous nebula.

The matter of which I have been speaking so far is the material which builds up the earth, the sun, and the stars, the matter studied by the chemist, and which he can represent by a formula; this matter occupies, however, but an insignificant fraction of the universe, it forms but minute islands in the great ocean of the ether, the substance with which the whole universe is filled.

The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. For we must remember that we on this earth are not living on our own resources; we are dependent from minute to minute upon what we are getting from the sun, and the gifts of the sun are conveyed to us by the ether. It is to the sun that we owe not merely night and day, springtime and harvest, but it is the energy of the sun, stored up in coal, in waterfalls, in food, that practically does all the work of the world.

How great is the supply the sun lavishes upon us becomes clear when we consider that the heat received by the earth under a high sun and a clear sky is equivalent, according to the measurements of Langley, to about 7,000 horse-power per acre. Though our engineers have not yet discovered how to utilise this enormous supply of power, they will, I have not the slightest doubt, ultimately succeed in doing so; and when coal is exhausted and our water-power inadequate it may be that this is the source from which we shall derive the energy necessary for the world's work. When that comes about our centres of industrial activity may, perhaps, be transferred to the burning deserts of the Sahara, and the value of land determined by its suitability for the reception of traps to catch sunbeams.

This energy, in the interval between its departure from the sun and its arrival at the earth, must be in the space between them. Thus this space must contain something which, like ordinary matter, can store up energy, which can carry at an enormous pace the energy associated with light and heat, and which can, in addition, exert the enormous stresses necessary to keep the earth circling round the sun and the moon round the earth.

The study of this all-pervading substance is, perhaps, the most fascinating and important duty of the physicist.

On the electromagnetic theory of light, now universally accepted, the energy streaming to the earth travels through the ether in electric waves; thus practically the whole of the energy at our disposal has at one time or another been electrical energy. The ether must, then, be the seat of electrical and magnetic forces. We know, thanks to the genius of Clerk Maxwell, the founder and inspirer of modern electrical theory, the equations which express the relation between these forces, and although for some purposes these are all we require, yet they do not tell us very much about the nature of the ether.

The interest inspired by equations, too, in some minds is apt to be somewhat Platonic; and something more grossly mechanical—a model, for example, is felt by many to be more suggestive and manageable, and for them a more powerful instrument of research, than a purely analytical theory.

Is the ether dense or rare? Has it a structure? Is it at rest or in motion? are some of the questions which force themselves upon us.

Let us consider some of the facts known about the ether. When light falls on a body and is absorbed by it, the body is pushed forward in the direction in which the light is travelling, and if the body is free to move it is set in motion by the light. Now it is a fundamental principle of dynamics that when a body is set moving in a certain direction, or, to use the language of dynamics, acquires momentum in that direction, some other mass must lose the same amount of momentum; in other words, the amount of momentum in the universe is constant. Thus when the body is pushed forward by the light some other system must have lost the momentum the body acquires, and the only other system available is the wave of light falling on the body; hence we conclude that there must have been momentum in the wave in the direction in which it is travelling. Momentum, however, implies mass in motion. We conclude, then, that in the ether through which the wave is moving there is mass moving with the velocity of light. The experiments made on the pressure due to light enable us to calculate this mass, and we find that in a cubic kilometre of ether carrying light as intense as sunlight is at the surface of the earth, the mass moving is only about one-fifty-millionth of a milligramme. We must be careful not to confuse this with the mass of a cubic kilometre of ether; it is only the mass moved when the light passes through it; the vast majority of the ether is left undisturbed by the light. Now, on the electro-magnetic theory of light, a wave of light may be regarded as made up of groups of lines of electric force moving with the velocity of light; and if we take this point of view we can prove that the mass of ether per cubic centimetre carried along is proportional to the energy possessed by these lines of electric force per cubic centimetre, divided by the square of the velocity of light. But though lines of electric force carry some of the ether along with them as they move, the amount so carried, even in the strongest electric fields we can produce, is but a minute fraction of the ether in their neighbourhood.

This is proved by an experiment made by Sir Oliver Lodge in which light was made to travel through an electric field in rapid motion. If the electric field had carried the whole of the ether with it, the velocity of the light would have been increased by the velocity of the electric field. As a matter of fact, no increase whatever could be detected, though it would have been registered if it had amounted to one-thousandth part of that of the field.

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The ether carried along by a wave of light must be an exceedingly small part of the volume through which the wave is spread. Parts of this volume are in motion, but by far the greater part is at rest; thus in the wave front there cannot be uniformity, at some parts the ether is moving, at others it is at rest—in other words, the wave front must be more analogous to bright specks on a dark ground than to a uniformly illuminated surface.

The place where the density of the ether carried along by an electric field rises to its highest value is close to a corpuscle, for round the corpuscles are by far the strongest electric fields of which we have any knowledge. We know the mass of the corpuscle, we know from Kaufmann's experiments that this arises entirely from the electric charge, and is therefore due to the ether carried along with the corpuscle by the lines of force attached to it.

A simple calculation shows that one-half of this mass is contained in a volume seven times that of a corpuscle. Since we know the volume of the corpuscle as well as the mass, we can calculate the density of the ether attached to the corpuscle; doing so, we find it amounts to the prodigious value of about 5×10^{10}, or about 2,000 million times that of lead. Sir Oliver Lodge, by somewhat different considerations, has arrived at a value of the same order of magnitude.

Thus around the corpuscle ether must have an extravagant density: whether the density is as great as this in other places depends upon whether the ether is compressible or not. If it is compressible, then it may be condensed round the corpuscles, and there have an abnormally great density; if it is not compressible, then the density in free space cannot be less than the number I have just mentioned.

With respect to this point we must remember that the forces acting on the ether close to the corpuscle are prodigious. If the ether were, for example, an ideal gas whose density increased in proportion to the pressure, however great the pressure might be, then if, when exposed to the pressures which exist in some directions close to the corpuscle, it had the density stated above, its density under atmospheric pressure would only be about 8×10^{-6}, or a cubic kilometre would have a mass less than a gramme; so that instead of being almost incomparably denser than lead, it would be almost incomparably rarer than the lightest gas.

I do not know at present of any effect which would enable us to determine whether ether is compressible or not. And although at first sight the idea that we are immersed in a medium almost infinitely denser than lead might seem inconceivable, it is not so if we remember that in all probability matter is composed mainly of holes. We may, in fact, regard matter as possessing a bird-cage kind of structure in which the volume of the ether disturbed by the wires when the structure is moved is infinitesimal in comparison with the volume enclosed by them. If we do this, no difficulty arises from the great density of the ether; all we have to do is to increase the distance between the wires in proportion as we increase the density of the ether.

Let us now consider how much ether is carried along by ordinary matter, and what effects this might be expected to produce.

The simplest electrical system we know, an electrified sphere, has attached to it a mass of ether proportional to its potential energy, and such that if the mass were to move with the velocity of light its kinetic energy would equal the electrostatic potential energy of the particle. This result can be extended to any electrified system, and it can be shown that such a system binds a mass of the ether proportional to its potential energy. Thus a part of the mass of any system is proportional to the potential energy of the system.

The question now arises, does this part of the mass add anything to the weight of the body? If the ether were not subject to gravitational attraction it certainly would not; and even if the ether were ponderable, we might expect that as the mass is swimming in a sea of ether it would not increase the weight of the body to which it is attached. But if it does not, then a body with a large amount of potential energy may have an appreciable amount of its mass in a form which does not increase its weight, and thus the weight of a given mass of it may be less than that of an equal mass of some substance with a smaller amount of potential energy. Thus the weights of equal masses of these substances would be different. Now, experiments with pendulums, as Newton pointed out, enable us to determine with great accuracy the weights of equal masses of different substances. Newton himself made experiments of this kind, and found that the weights of equal masses were the same for all the materials he tried. Bessel, in 1830, made some experiments on this subject which are still the most accurate we possess, and he showed that the weights of equal masses of lead, silver, iron, brass did not differ by as much as one part in 60,000.

The substances tried by Newton and Bessel did not, however, include any of those substances which possess the marvellous power of radioactivity; the discovery of these came much later, and is one of the most striking achievements of modern physics.

These radio-active substances are constantly giving out large quantities of heat, presumably at the expense of their potential energy; thus when these substances reach their final non-radio-active state their potential energy must be less than when they were radio-active. Professor Rutherford's measurements show that the energy emitted by one gramme of radium in the course of its degradation to non-radio-active forms is equal to the kinetic energy of a mass of 1-13th of a milligramme moving with the velocity of light.

This energy, according to the rule I have stated, corresponds to a mass of 1-13th of a milligramme of the ether, and thus a gramme of radium in its radio-active state must have at least 1-13th of a milligramme more of ether attached to it than when it has been degraded into the non-radio-active forms. Thus if this ether does not increase the weight of the radium, the ratio of mass to weight for radium would be greater by about one part in 13,000 than for its non-radio-active products.

I attempted several years ago to find the ratio of mass to weight for radium by swinging a little pendulum, the bob of which was made of radium. I had only a small quantity of radium, and was not, therefore, able to attain any great accuracy. I found that the difference, if any, in the ratio of the mass to weight between radium and other substances was not more than one part in 2,000. Lately we have been using at the Cavendish Laboratory a pendulum whose bob was filled with uranium oxide. We have got good reasons for supposing that uranium is a parent of radium, so that the great potential energy and large ethereal mass possessed by the radium will be also in the uranium; the experiments are not yet completed. It is, perhaps, expecting almost too much to hope that the radio-active substances may add to the great services they have already done to science by furnishing the first case in which there is some differentiation in the action of gravity.

The mass of ether bound by any system is such that if it were to move with the velocity of light its kinetic energy would be equal to the potential energy of the system. This result suggests a new view of the nature of potential energy. Potential energy is usually regarded as essentially different from kinetic energy. Potential energy depends on the configuration of the system, and can be calculated from it when we have the requisite data; kinetic energy, on the other hand, depends upon the velocity of the system. According to the principle of the conservation of energy the one form can be converted into the other at a fixed rate of exchange, so that when one unit of one kind disappears a unit of the other simultaneously appears.

Now in many cases this rule is all that we require to calculate the behaviour of the system, and the conception of potential energy is of the utmost value in making the knowledge derived from experiment and observation available for mathematical calculation. It must, however, I think, be admitted that from the purely philosophical point of view it is open to serious objection. It violates, for example, the principle of continuity. When a thing changes from a state A to a different state B, the principle of continuity requires that it must pass through a number of states intermediate between A and B, so that the transition is made gradually, and not abruptly. Now, when kinetic

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energy changes into potential, although there is no discontinuity in the quantity of the energy, there is in its quality, for we do not recognise any kind of energy intermediate between that due to the motion and that due to the position of the system, and some portions of energy are supposed to change *per saltum* from the kinetic to the potential form. In the case of the transition of kinetic energy into heat energy in a gas, the discontinuity has disappeared with a fuller knowledge of what the heat energy in a gas is due to. When we were ignorant of the nature of this energy, the transition from kinetic into thermal energy seemed discontinuous; but now we know that this energy is the kinetic energy of the molecules of which the gas is composed, so that there is no change in the type of energy when the kinetic energy of visible motion is transformed into the thermal energy of a gas—it is just the transference of kinetic energy from one body to another.

If we regard potential energy as the kinetic energy of portions of the ether attached to the system, then all energy is kinetic energy, due to the motion of matter or of portions of ether attached to the matter. I showed, many years ago, in my "Applications of Dynamics to Physics and Chemistry," that we could imitate the effects of the potential energy of a system by means of the kinetic energy of invisible systems connected in an appropriate manner with the main system, and that the potential energy of the visible universe may in reality be the kinetic energy of an invisible one connected up with it. We naturally suppose that this invisible universe is the luminiferous ether, that portions of the ether in rapid motion are connected with the visible systems, and that their kinetic energy is the potential energy of the systems.

We may thus regard the ether as a bank in which we may deposit energy and withdraw it at our convenience. The mass of the ether attached to the system will change as the potential energy changes, and thus the mass of a system whose potential energy is changing cannot be constant; the fluctuations in mass under ordinary conditions are, however, so small that they cannot be detected by any means at present at our disposal. Inasmuch as the various forms of potential energy are continually being changed into heat energy, which is the kinetic energy of the molecules of matter, there is a constant tendency for the mass of a system such as the earth or the sun to diminish, and thus as time goes on for the mass of ether gripped by the material universe to become smaller and smaller; the rate at which it would diminish would, however, get slower as time went on, and there is no reason to think that it would ever get below a very large value.

Radiation of light and heat from an incandescent body like the sun involves a constant loss of mass by the body. Each unit of energy radiated carries off its quota of mass, but as the mass ejected from the sun per year is only one part in 20 billionths (1 in 2×10^{18}) of the mass of the sun, and as this diminution in mass is not necessarily accompanied by any decrease in its gravitational attraction, we cannot expect to be able to get any evidence to this effect.

As our knowledge of the properties of light has progressed, we have been driven to recognise that the ether, when transmitting light, possesses properties which, before the introduction of the electro-magnetic theory, would have been thought to be peculiar to an emission theory of light and to be fatal to the theory that light consists of undulations.

Take, for example, the pressure exerted by light. This would follow as a matter of course if we supposed light to be small particles moving with great velocities, for these, if they struck against a body, would manifestly tend to push it forward, while on the undulatory theory there seemed no reason why any effect of this kind should take place.

Indeed, in 1792, this very point was regarded as a test between the theories, and Bennet made experiments to see whether or not he could find any traces of this pressure. We now know that the pressure is there, and if Bennet's instrument had been more sensitive he must have observed it. It is perhaps fortunate that Bennet had not at his command more delicate apparatus. Had he discovered the pressure of light, it would have shaken confidence in the undulatory theory and checked that magnificent work at the beginning of the last century which so greatly increased our knowledge of optics.

As another example, take the question of the distribution of energy in a wave of light. On the emission theory the energy in the light is the kinetic energy of the light particles. Thus the energy of light is made up of distinct units, the unit being the energy of one of the particles.

The idea that the energy has a structure of this kind has lately received a good deal of support. Planck, in a very remarkable series of investigations on the Thermodynamics of Radiation, pointed out that the expressions for the energy and entropy of radiant energy were of such a form as to suggest that the energy of radiation, like that of a gas on the molecule theory, was made up of distinct units, the magnitude of the unit depending on the colour of the light; and on this assumption he was able to calculate the value of the unit, and from this deduce incidentally the value of Avogadro's constant—the number of molecules in a cubic centimetre of gas at standard temperature and pressure.

This result is most interesting and important because if it were a legitimate deduction from the Second Law of Thermodynamics, it would appear that only a particular type of mechanism for the vibrators which give out light and the absorbers which absorb it could be in accordance with that law.

If this were so, then, regarding the universe as a collection of machines all obeying the laws of dynamics, the Second Law of Thermodynamics would only be true for a particular kind of machine.

There seems, however, grave objection to this view, which I may illustrate by the case of the First Law of Thermodynamics, the principle of the Conservation of Energy. This must be true whatever be the nature of the machines which make up the universe; provided they obey the laws of dynamics, any application of the principle of the Conservation of Energy could not discriminate between one type of machine and another.

Now, the Second Law of Thermodynamics, though not a dynamical principle in as strict a sense as the law of the Conservation of Energy, is one that we should expect to hold for a collection of a large number of machines of any type, provided that we could not directly affect the individual machines, but could only observe the average effects produced by an enormous number of them. On this view, the Second Law, as well as the First, should be incapable of saying that the machines were of any particular type; so that investigations founded on thermodynamics, though the expressions they lead to may suggest—cannot, I think, be regarded as proving—the unit structure of light energy.

It would seem as if in the application of thermodynamics to radiation some additional assumption has been implicitly introduced, for these applications lead to definite relations between the energy of the light of any particular wave length and the temperature of the luminous body.

Now a possible way of accounting for the light emitted by hot bodies is to suppose that it arises from the collisions of corpuscles with the molecules of the hot body, but it is only for one particular law of force between the corpuscles and the molecules that the distribution of energy would be the same as that deduced by the Second Law of Thermodynamics, so that in this case, as in the other, the results obtained by the application of thermodynamics to radiation would require us to suppose that the Second Law of Thermodynamics is only true for radiation when the radiation is produced by mechanism of a special type.

Quite apart, however, from considerations of thermodynamics, we should expect that the light from a luminous source should in many cases consist of parcels, possessing, at any rate to begin with, a definite amount of energy. Consider, for example, the case of a gas like sodium vapour, emitting light of a definite wave length; we may imagine that this light, consisting of electrical waves, is emitted by systems resembling Leyden jars. The energy originally possessed by such a system will be the electrostatic energy of the charged jar. When the vibrations are started, this energy will be radiated away into space, the radiation forming a complex system, containing, if the jar has no electrical resistance, the energy stored up in the jar.

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The amount of this energy will depend on the size of the jar and the quantity of electricity with which it is charged. With regard to the charge, we must remember that we are dealing with systems formed out of single molecules, so that the charge will only consist of one or two natural units of electricity, or, at all events, some small multiple of that unit, while for geometrically similar Leyden jars the energy for a given charge will be proportional to the frequency of the vibration; thus, the energy in the bundle of radiation will be proportional to the frequency of the vibration.

We may picture to ourselves the radiation as consisting of the lines of electric force which, before the vibrations were started, were held bound by the charges on the jar, and which, when the vibrations begin, are thrown into rhythmic undulations, liberated from the jar and travel through space with the velocity of light.

Now let us suppose that this system strikes against an uncharged condenser and gives it a charge of electricity, the charge on the plates of the condenser must be at least one unit of electricity, because fractions of this charge do not exist, and each unit charge will anchor a unit tube of force, which must come from the parcel of radiation falling upon it. Thus a tube in the incident light will be anchored by the condenser, and the parcel formed by this tube will be anchored and withdrawn as a whole from the pencil of light incident on the condenser. If the energy required to charge up the condenser with a unit of electricity is greater than the energy in the incident parcel, the tube will not be anchored and the light will pass over the condenser and escape from it. These principles that radiation is made up of units, and that it requires a unit possessing a definite amount of energy to excite radiation in a body on which it falls, perhaps receive their best illustration in the remarkable laws governing Secondary Röntgen radiation, recently discovered by Professor Barkla. Professor Barkla has found that each of the different chemical elements, when exposed to Röntgen rays, emit a definite type of secondary radiation whatever may have been the type of primary, thus lead emits one type, copper another, and so on; but these radiations are not excited at all if the primary radiation is of a softer type than the specific radiation emitted by the substance; thus the secondary radiation from lead being harder than that from copper; if copper is exposed to the secondary radiation from lead the copper will radiate, but lead will not radiate when exposed to copper. Thus, if we suppose that the energy in a unit of hard Röntgen rays is greater than that in one of soft, Barkla's results are strikingly analogous to those which would follow on the unit theory of light.

Though we have, I think, strong reasons for thinking that the energy in the light waves of definite wave length is done up into bundles, and that these bundles, when emitted, all possess the same amount of energy, I do not think there is any reason for supposing that in any casual specimen of light of this wave length, which may subsequent to its emission have been many times refracted or reflected, the bundles possess any definite amount of energy. For consider what must happen when a bundle is incident on a surface such as glass, when part of it is reflected and part transmitted. The bundle is divided into two portions, in each of which the energy is less than the incident bundle, and since these portions diverge and may ultimately be many thousands of miles apart, it would seem meaningless to still regard them as forming one unit. Thus the energy in the bundles of light, after they have suffered partial reflection, will not be the same as in the bundles when they were emitted. The study of the dimensions of these bundles, for example, the angle they subtend at the luminous source, is an interesting subject for investigation; experiments on interference between rays of light emerging in different directions from the luminous source would probably throw light on this point.

I now pass to a very brief consideration of one of the most important and interesting advances ever made in physics, and in which Canada, as the place of the labours of Professors Rutherford and Soddy, has taken a conspicuous part. I mean the discovery and investigation of radio-activity. Radio-activity was brought to light by the Röntgen rays. One of the many remarkable properties of these rays is to excite phosphorescence in certain substances, including the salts of uranium, when they fall upon them. Since Röntgen rays produce phosphorescence, it occurred to Becquerel to try whether phosphorescence would produce Röntgen rays. He took some uranium salts which had been made to phosphoresce by exposure, not to Röntgen rays but to sunlight, tested them, and found that they gave out rays possessing properties similar to Röntgen rays. Further investigation showed, however, that to get these rays it was not necessary to make the uranium phosphoresce, that the salts were just as active if they had been kept in the dark. It thus appeared that the property was due to the metal and not to the phosphorescence, and that uranium and its compounds possessed the power of giving out rays which, like Röntgen rays, affect a photographic plate, make certain minerals phosphoresce, and make gases through which they pass conductors of electricity.

Niepce de Saint-Victor had observed some years before this discovery that paper soaked in a solution of uranium nitrate affected a photographic plate, but the observation excited but little interest. The ground had not then been prepared, by the discovery of the Röntgen rays, for its reception, and it withered and was soon forgotten.

Shortly after Becquerel's discovery of uranium, Schmidt found that thorium possessed similar properties. Then Monsieur and Madame Curie, after a most difficult and laborious investigation, discovered two new substances, radium and polonium, possessing this property to an enormously greater extent than either thorium or uranium, and this was followed by the discovery of actinium by Debierne. Now the researches of Rutherford and others have led to the discovery of so many new radio-active substances that any attempts at christening seem to have been abandoned, and they are denoted, like policemen, by the letters of the alphabet.

Mr. Campbell has recently found that potassium, though far inferior in this respect to any of the substances I have named, emits an appreciable amount of radiation, the amount depending only on the quantity of potassium, and being the same whatever the source from which the potassium is obtained or whatever the elements with which it may be in combination.

The radiation emitted by these substances is of three types known as α, β and γ rays. The α rays have been shown by Rutherford to be positively electrified atoms of helium, moving with speeds which reach up to about one-tenth of the velocity of light. The β rays are negatively electrified corpuscles, moving in some cases with very nearly the velocity of light itself, while the γ rays are uneiectrified, and are analogous to the Röntgen rays.

The radio-activity of uranium was shown by Crookes to arise from something mixed with the uranium, and which differed sufficiently in properties from the uranium itself to enable it to be separated by chemical analysis. He took some uranium, and by chemical treatment separated it into two portions, one of which was radio-active and the other not.

Next Becquerel found that if these two portions were kept for several months, the part which was not radio-active to begin with regained radio-activity, while the part which was radio-active to begin with had lost its radio-activity. These effects and many others receive a complete explanation by the theory of radio-active change which we owe to Rutherford and Soddy.

According to this theory, the radio-active elements are not permanent, but are gradually breaking up into elements of lower atomic weight; uranium, for example, is slowly breaking up, one of the products being radium, while radium breaks up into a radio-active gas called radium emanation, the emanation into another radio-active substance, and so on, and that the radiations are a kind of swan's song emitted by the atoms when they pass from one form to another; that, for example, it is when a radium atom breaks up and an atom of the emanation appears that the rays which constitute the radio-activity are produced.

Thus, on this view the atoms of the radio-active elements are not immortal, they perish after a life whose average value ranges from thousands of millions of years in the case of uranium, to a second or so in the case of the gaseous emanation from actinium.

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When the atoms pass from one state to another they give out large stores of energy, thus their descendants do not inherit the whole of their wealth of stored-up energy, the estate becomes less and less wealthy with each generation; we find, in fact, that the politician, when he imposes death duties, is but imitating a process which has been going on for ages in the case of these radio-active substances.

Many points of interest arise when we consider the rate at which the atoms of a radio-active substance disappear. Rutherford has shown that whatever be the age of these atoms, the percentage of atoms which disappear in one second is always the same; another way of putting it is that the expectation of life of an atom is independent of its age—that an atom of radium one thousand years old is just as likely to live for another thousand years as one just sprung into existence.

Now this would be the case if the death of the atom were due to something from outside which struck old and young indiscriminately; in a battle, for example, the chance of being shot is the same for old and young; so that we are inclined at first to look to something coming from outside as the cause why an atom of radium, for example, suddenly changes into an atom of the emanation. But here we are met with the difficulty that no changes in the external conditions that we have as yet been able to produce have had any effect on the life of the atom; as far as we know at present the life of a radium atom is the same at the temperature of a furnace as at that of liquid air—it is not altered by surrounding the radium by thick screens of lead or other dense materials to ward off radiation from outside, and, what to my mind is especially significant, it is the same when the radium is in the most concentrated form, when its atoms are exposed to the vigorous bombardment from the rays given off by the neighbouring atoms, as when it is in the most dilute solution, when the rays are absorbed by the water which separates one atom from another. This last result seems to me to make it somewhat improbable that we shall be able to split up the atoms of the non-radio-active elements by exposing them to the radiation from radium; if this radiation is unable to affect the unstable radio-active atoms, it is somewhat unlikely that it will be able to affect the much more stable non-radio-active elements.

The evidence we have at present is against a disturbance coming from outside breaking up of the radio-active atoms, and we must therefore look to some process of decay in the atom itself; but if this is the case, how are we to reconcile it with the fact that the expectation of life of an atom does not diminish as the atom gets older? We can do this if we suppose that the atoms when they are first produced have not all the same strength of constitution, that some are more robust than others, perhaps because they contain more intrinsic energy to begin with, and will therefore have a longer life. Now, if when the atoms are first produced there are some which will live for one year, some for ten, some for a thousand, and so on; and if lives of all durations, from nothing to infinity, are present in such proportion that the number of atoms which will live longer than a certain number of years decrease in a constant proportion for each additional year of life, we can easily prove that the expectation of life of an atom will be the same whatever its age may be. On this view the different atoms of a radio-active substance are not, in all respects, identical.

The energy developed by radio-active substances is exceedingly large, one gramme of radium developing nearly as much energy as would be produced by burning a ton of coal. This energy is mainly in the α particles, the positively charged helium atoms, which are emitted when the change in the atom takes place; if this energy were produced by electrical forces it would indicate that the helium atom had moved through a potential difference of about two million volts on its way out of the atom of radium. The source of this energy is a problem of the deepest interest; if it arises from the repulsion of similarly electrified systems exerting forces varying inversely as the square of the distance, then to get the requisite amount of energy the systems, if their charges were comparable with the charge on the α particle, could not when they start be further apart than the radius of a corpuscle, 10^{-13} cm. If we suppose that the particles do not acquire this energy at the explosion, but that before they are shot out of the radium atom they move in circles inside this atom with the speed with which they emerge, the forces required to prevent particles moving with this velocity from flying off at a tangent are so great that finite charges of electricity could only produce them at distances comparable with the radius of a corpuscle.

One method by which the requisite amount of energy could be obtained is suggested by the view to which I have already alluded—that in the atom we have electrified systems of very different types, one small, the other large; the radius of one type is comparable with 10^{-13} cm., that of the other is about 100,000 times greater. The electrostatic potential energy in the smaller bodies is enormously greater than that in the larger ones; if one of these small bodies were to explode and expand to the size of the larger ones, we should have a liberation of energy large enough to endow an particle with the energy it possesses. Is it possible that the positive units of electricity were, to begin with, quite as small as the negative, but while in the course of ages most of these have passed from the smaller stage to the larger, there are some small ones still lingering in radio-active substances, and it is the explosion of these which liberates the energy set free during radio-active transformation?

The properties of radium have consequences of enormous importance to the geologist as well as to the physicist or chemist. In fact, the discovery of these properties has entirely altered the aspect of one of the most interesting geological problems, that of the age of the earth. Before the discovery of radium it was supposed that the supplies of heat furnished by chemical changes going on in the earth were quite insignificant, and that there was nothing to replace the heat which flows from the hot interior of the earth to the colder crust. Now when the earth first solidified it only possessed a certain amount of capital in the form of heat, and if it is continually spending this capital and not gaining any fresh heat, it is evident that the process cannot have been going on for more than a certain number of years, otherwise the earth would be colder than it is. Lord Kelvin in this way estimated the age of the earth to be less than 100 million years. Though the quantity of radium in the earth is an exceedingly small fraction of the mass of the earth, only amounting, according to the determinations of Professors Strutt and Joly, to about five grammes in a cube whose side is 100 miles, yet the amount of heat given out by this small quantity of radium is so great that it is more than enough to replace the heat which flows from the inside to the outside of the earth. This, as Rutherford has pointed out, entirely vitiates the previous method of determining the age of the earth. The fact is that the radium gives out so much heat that we do not quite know what to do with it, for if there was as much radium throughout the interior of the earth as there is in its crust, the temperature of the earth would increase much more rapidly than it does as we descend below the earth's surface. Professor Strutt has shown that if radium behaves in the interior of the earth as it does at the surface, rocks similar to those in the earth's crust cannot extend to a depth of more than forty-five miles below the surface.

It is remarkable that Professor Milne from the study of earthquake phenomena had previously come to the conclusion that rocks similar to those at the earth's surface only descend a short distance below the surface; he estimates this distance at about thirty miles, and concludes that at a depth greater than this the earth is fairly homogeneous.

Though the discovery of radio-activity has taken away one method of calculating the age of the earth it has supplied another.

The gas helium is given out by radio-active bodies, and since, except in beryls, it is not found in minerals which do not contain radio-active elements, it is probable that all the helium in these minerals has come from these elements. In the case of a mineral containing uranium, the parent of radium, in radio-active equilibrium, with radium and its products, helium will be produced at a definite rate. Helium, however, unlike the radio-active elements, is per-

manent and accumulates in the mineral; hence if we measure the amount of helium in a sample of rock and the amount produced by the sample in one year we can find the length of time the helium has been accumulating, and hence the age of the rock. This method, which is due to Professor Strutt, may lead to determinations not merely of the average age of the crust of the earth, but of the ages of particular rocks and the date at which the various strata were deposited; he has, for example, shown in this way that a specimen of the mineral thorianite must be more than 240 million years old.

The physiological and medical properties of the rays emitted by radium is a field of research in which enough has already been done to justify the hope that it may lead to considerable alleviation of human suffering. It seems quite definitely established that for some diseases, notably rodent ulcer, treatment with these rays has produced remarkable cures; it is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for. Radium is, however, so costly that few hospitals could afford to undertake pioneering work of this kind; fortunately, however, through the generosity of Sir Ernest Cassel and Lord Iveagh, a Radium Institute, under the patronage of His Majesty the King, has been founded in London for the study of the medical properties of radium, and for the treatment of patients suffering from diseases for which radium is beneficial.

The new discoveries made in physics in the last few years, and the ideas and potentialities suggested by them, have had an effect upon the workers in that subject akin to that produced in literature by the Renaissance. Enthusiasm has been quickened, and there is a hopeful, youthful, perhaps exuberant, spirit abroad which leads men to make with confidence experiments which would have been thought fantastic twenty years ago. It has quite dispelled the pessimistic feeling, not uncommon at that time, that all the interesting things had been discovered, and all that was left was to alter a decimal or two in some physical constant. There never was any justification for this feeling, there never were any signs of an approach to finality in science. The sum of knowledge is at present, at any rate, a diverging, not a converging, series. As we conquer peak after peak we see in front of us regions full of interest and beauty, but we do not see our goal, we do not see the horizon; in the distance tower still higher peaks, which will yield to those who ascend them still wider prospects, and deepen the feelings, whose truth is emphasised by every advance in science, that "Great are the Works of the Lord."

Photography: Pure and Applied.

By CHAPMAN JONES, F.I.C., F.C.S., &c.

Lens Testing at the National Physical Laboratory.

The opportunity of having photographic objectives tested at Kew and later at the National Physical Laboratory has never been taken much advantage of. The number submitted during the first year that the testing was undertaken was nineteen and in the subsequent years the numbers were 18, 31, 27, 14, 14, 10, and so on, while the year before last twenty-nine were submitted, and last year seventeen. Considering the many thousands of lenses that are made every year, these numbers are quite insignificant. In order to reduce the cost of examination, which is only a few shillings, makers who wish to send lenses regularly, will in future have the opportunity of depositing at the laboratory a sample of any type, and this will be tested with the greatest care. Then lenses of the same kind will be compared with this standard to see that the quality is maintained; and such comparison will be a considerably shorter piece of work than the independent examination of a lens, and the charge for it less.

Still we may well ask why is it that after the opportunity of having lenses tested by an independent authority has existed for just upon twenty years, so small a number, and not an increasing number, of lenses have been sent. It may not be generally known, although it is a fact, that those responsible for the testing have not adhered to the methods at first employed, which, for want of experience, were bound to be of a more or less tentative character, but have improved both the methods and appliances, so that now, without doubt, they probably have a better equipment for this purpose than any optician or any other institution. The advantage of the testing is that it is quantitative, reliable, and independent of the bias which a maker or owner might suffer from. But, I think, that the chief reason why the opportunity is so little appreciated, is that a lens is not an instrument like a watch of which everyone knows exactly and absolutely what he desires. The only use of a watch is to keep time, and in the testing of it, its power to do this in different positions and at different temperatures is determined directly, and the errors that it shows are expressed in terms that every user of a watch can understand. It is entirely different with a lens. The one function of a lens is to produce an image. But it is not possible to express in a simple and direct way its failure to do so. Its faults are separately estimated, and the result would be analogous in the case of the watch if its parts were separately tested for perfection of workmanship and expressed in mechanical terms which few others than watch makers could understand. No ordinary person could deduce from a measurement of the errors in the mechanical construction of a watch its power to keep good time, and just so ordinary users of lenses cannot form an idea of the perfection of the image-producing power of a lens from a statement of its various optical errors. Moreover, this image-producing power is not a definite and absolute property like the time-keeping power of a watch. If a lens proves to be inferior in practical work, the photographer, as a rule, does not care why it is inferior, nor does a knowledge of this in any way help him.

Therefore it appears that the official lens-testing is not likely to be ever very largely taken advantage of, and that the optician and the photographer will generally prefer to do their own testing in their own way. At the same time there are many cases where official and independent testing offers advantages not otherwise obtainable. In photo-mechanical work, for example, the performance required of the lens is much more definite than in the greater number of other cases, and its comparative excellence can be expressed more definitely in practical units. With regard to lenses for general purposes, if it were possible to include on the certificate the average results obtained by the examination of lenses of different kinds, with some indication of the range of errors found, as, for example that five or ten per cent. are above or below a certain degree of perfection, and on this to show the position found for the given instrument, then a glance would show whether the lens was an average sample of its class or whether it was exceptionally good or otherwise. A good "rapid rectilinear" might in some details be superior to a low-class anastigmat, and if the general range of these two classes was expressed with the result of the test, this fact would be obvious

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at a glance. What the ordinary person wants to know is whether a given lens is good of its kind, or whether another kind is likely to offer advantages proportional to its difference in cost for the work he has to do, and it is not easy to answer such questions from certificates that give no indication of the average degree of perfection attained in lenses of different classes.

Shutter Testing. An apparatus for testing photographic exposure shutters has been elaborated at the National Physical Laboratory, and presumably such testing will be undertaken very shortly. The method employed is according to well-known principles, the timing arrangement being a vibrating mirror which gives on the plate a sinuous curve. The vibration of the small mirror has sometimes been obtained by attaching it to a tuning fork. The many objections to this particular method are overcome by the use of a vibration galvanometer, an instrument in which the amplitude and the frequency of the vibrations are under easy control. The reflected pencil of light falls upon a moving plate for the period that the interposed shutter is open, and the number of oscillations recorded gives at once, knowing the rate of oscillation, the period of the exposure. Efficiency is estimated after the method described by Sir William Abney.

The testing of shutters is a very different matter from the testing of lenses. The durations of the exposures that they give is expressed as a simple period of time, and the efficiency, that is, the time necessary to produce the same light-effect on the plate supposing that the shutter was open at its full for the whole time, can generally be expressed in a way that is easy to understand, though the matter is not quite so simple as it may appear to be at first sight. Therefore it is to be hoped that the privilege of being able to get such reliable and unbiassed estimations will be fully appreciated, and that the proportion of shutters that do not give even approximately the exposures that are marked on them, which at present is very large, will before long be reduced to negligible proportions.

New Development Papers. The Paget Prize Plate Company has introduced a "Phosphate" paper, which gives images of a range of colours that need no subsequent toning. The developer is an acid solution of metol, and acts presumably by dissolving the silver salt from the paper and then deposing metallic silver on the latent image.

Messrs. Houghton are now issuing their well-known "Ensyna" paper in three new varieties, "vigorous glossy," "vigorous matt," and "carbon," and will send details of them, free, to any applicant. I hope to refer again to these papers when I have had experience of them.

Solar Disturbances During July, 1909.

By FRANK C. DENNETT.

DURING July there has been a slight revival in solar activity, although no dark spots were seen on 11th. On July 1, at noon, the longitude of the central meridian was 340° 46′.

No. 63 remained visible until July 6, and so re-appears upon the present chart.

No. 65.—A solitary pore seen July 1 to 3.

No. 66.—A larger pore with smaller ones in rear, 28,000 miles in length, 5th to 8th.

No. 67.—A faculic disturbance enclosed two larger and some smaller pores, the group being 30,000 miles in length, 8th, dying out before 11th.

No. 68.—A single pore only visible on 13th.

No. 69.—On 13th about five pores within 37,000 miles, by 14th the length had increased to 59,000 miles, but which seemed dying out next morning. However, in the afternoon it revived, and on 17th contained small spots, the leader 6,000 miles in diameter. Only one pore remained 19th when last seen.

No. 70.—A considerable spot close to limb on 15th, which was soon seen to have small companions, the group on 20th reaching 60,000 miles in length. On 22nd it seemed dwindling, but on 24th had much increased again, the leader assumed a form not unlike a comma 27,000 in diameter, and spotlets had again developed in its rear. Rapid changes occurred until last seen, 28th.

No. 70*a*.—Two small spots first seen 24th, 2° south of 70, which quickly increased their distance apart. Other spotlets appeared, making this disturbance 52,000 miles in length. Last seen 27th.

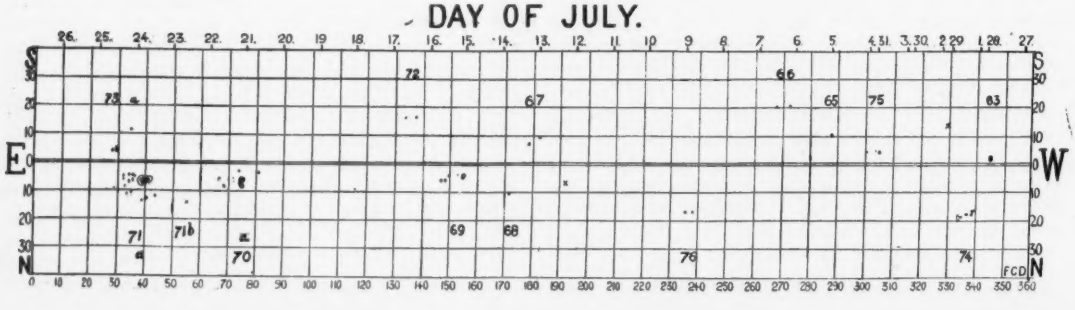
No. 71.—Considerable activity of the chromosphere on 17th heralded the appearance next day of this spot, which was soon seen to have smaller companions. On 22nd the leader had become double and was 35,000 miles in diameter, but the maximum was on 23rd, when the spot had still further increased in area, its umbra being decidedly red in colour in the morning, and the group was 83,000 miles in length, the whole being a naked-eye object. It now began to show rapid decrease in its train, only one companion remaining 28th. Last seen 30th.

No. 71*a*.—Pores in a faculic bed a little north of the last, on 22nd forming a line 68,000 miles in length. 19-24th.

No. 71*b*.—A single pore only seen 22nd.

No. 72.—Two pores, 28,000 miles apart, only seen 19th.

No. 73.—A spotlet on 19th, evidently grown 20th in a bright area. A companion 22nd, the larger spot appeared broken in two on 24th. A dwindling spotlet only 26-28th.



No. 73*a*.—A pore only seen 22nd.

No. 74.—A spot 22nd, with a companion 23rd, leading a group 24th, with larger members 26th. July 31 to August 3 a single spot. The greatest diameter of the spot 12,000 miles, the group reaching 53,000 miles in length. The area around was very faculic.

No. 75.—On 31st a black spot opened almost close to the central meridian, reaching 5,000 miles in diameter. This appeared split into two next day, and two companions in the rear made the group 37,000 miles in length on 2nd. Only the leader seen 3rd and 4th, when it was reduced to a pore.

No. 76.—Two pores amid a faculic mass, 21,000 miles apart, only seen on 31st.

Besides the above, on 2nd a pair of pores were recorded, but not measured at about longitude 326°, south latitude 13°; and and on 18th a small spot near longitude 192°, north latitude 7°; these are both marked by a tiny cross. (The first-mentioned is shown 3° too far to west.)

The chart has, as usual, been constructed from the combined observations of Messrs. J. McHarg, A. A. Buss, E. E. Peacock, and the writer.

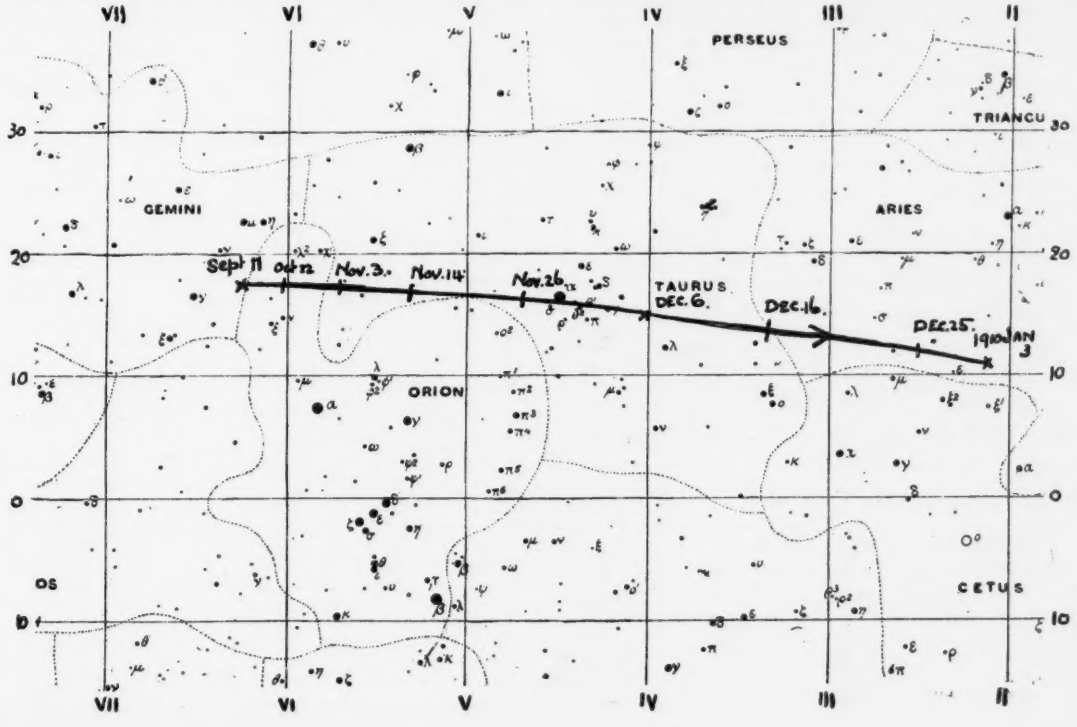
NOTES.

ASTRONOMY.

By CHARLES P. BUTLER, A.R.C.Sc. (Lond.), F.R.P.S., F.R.A.S.

IDENTIFICATION OF HITHERTO UNKNOWN LINES IN ORION STARS.—The spectra of the chief stars in Orion show various groupings of lines which enable us to formulate a somewhat detailed classification of the members of the series. According to Lockyer's temperature classification, these stars are considered to be of comparatively high temperature, as indicated by the relative intensities of the lines of silicon, helium, oxygen and nitrogen in their spectra. One of these interesting groups is represented by the star ϵ Orionis (Alnitam), and although most of the lines in its spectrum have been traced to the terrestrial elements producing them, a few have remained unknown until quite recently, notably lines at the wave-lengths 4097.4, 4379.8, and 4647.6-4650.8. In a paper read before the Royal Society, under the authorship of Sir Norman Lockyer, F. E. Baxandall, and C. P. Butler, a series of laboratory experiments are described, showing that, under certain definite conditions, these lines in ϵ Orionis may be matched with lines of the terrestrial elements, nitrogen and carbon. The 4097.4 line is one of a pair, the less responsible member having a wave-length 4103.5, which is so near the strong hydrogen line 4101.8 (Hδ) in the stellar spectrum that it cannot be certainly separated. By sparking nitrogen under very high electric tension it was found that two lines coinciding with these positions were relatively increased in intensity, and as the lines could not be produced from any other gas, it is practically proved that the strange lines are due to nitrogen. In similar manner it was found that there was another line of abnormal behaviour under the high tension spark of nitrogen near the wave-length 4379.8, and numerous check comparisons led to the conclusion that this was coincident with the stellar line.

In the case of the prominent double line at 4647.6-4650.8, several photographs showed marked intensification on either side of the strong oxygen line at 4649.2; the intensification was never observed in gases which did not show traces of the carbon line at 4267, and the final investigation of the high-tension spark of graphite in an atmosphere of hydrogen showed a new double line so nearly identical in position and structure with the stellar double that there is little doubt as to the correctness of the identification with carbon. That the substance involved is carbon, and not a compound of carbon and hydrogen, is proved by the statement that the new double was as well pronounced in an atmosphere of SO_2, containing no trace of hydrogen. We have from this considerable further evidence that the elements carbon and hydrogen are of great importance in



the spectrum of Orion stars of the ϵ Orionis type, and the knowledge of the exact laboratory conditions necessary to produce this type becomes of considerable interest in dealing with stellar evolution and classification.

SEARCH EPHEMERIS FOR HALLEY'S COMET.—Mr. A. C. D. Crommelin's ephemeris for observers wishing to take part in the search for this comet is as follows :—

	R.A.	Decl.
1909, Sept. 11·9	6 18 4	+ 17° 16′N.
,, 25·7	6 18 32	17 11
Oct. 9·1	6 14 36	17 8
,, 22·0	6 4 52	17 2
Nov. 3·3	5 47 4	16 59
,, 14·9	5 20 32	16 48
,, 25·7	4 45 8	16 22
Dec. 6·1	4 2 16	15 26
,, 15·7	3 18 20	14 6
,, 25·0	2 37 40	12 30
1910, Jan. 3·3	2 3 56	+ 10° 58′N.

From this it will be seen that the projected path of the comet passes from near γ Geminorum in a south-westerly direction towards the junction of the constellations Aries and Cetus, being very near ϵ Arietis towards the end of the year.

SPECTROSCOPIC BINARY β ORIONIS.—The variability of radial velocity in this system was first suspected by Vogel and Scheiner, working at Potsdam in the interval 1881-1891, their values ranging from +3 to + 34 km. per second, but no satisfactory evidence of periodicity could be obtained. In 1901-1902 Frost and Adams found velocities ranging from + 14.9 to + 23.4 kms., but they attributed the apparent variability to peculiarities in the spectrum lines which affected the measures. Observations at Lick by Campbell and Curtis showed a range from +15 to + 25 km., but they again did not consider that any real variation had been definitely shown. In a series of plates taken at the Ottawa Observatory, Mr. J. S. Plaskett found that the mean velocity of twelve plates taken on March 20, 1908, differed by over 5 km. per second from that of ten plates obtained four nights later, on March 24, and as special precautions had been taken to eliminate previous difficulties and sources of error, this suggested a real variation of the radial velocity. Plates were taken whenever possible, the number available for measurement being 275, obtained on 55 nights. In the reductions the only spectrum lines employed were λ 4481 (Mg); λ 4472 (He); and λ 4341 (Hγ). An early inspection of the reductions indicated a period of about 22 days, and the more definite reduction confirmed this value at about 21.90. In addition, there is strong evidence of a change of the amplitude of variation, which may be due to a third body. The mean curve derived from the measures is given, and the elements of the orbit deduced from it.

ELEMENTS OF ORBIT OF SPECTROSCOPIC BINARY β ORINIS.

Eccentricity ..	= 0·296 ± ·059
Semi-amplitude ..	= 3·771 ± ·210 km.
Longitude of apse	= 254°·76 ± 3°·48
Periastron passage	= 7·80 = J.D. 2,417,968 80
Period	= 21·90 days
Velocity of system	= + 22·616 ± ·158 km.
Semi-axis major ..	= 1,108,900 km.
Maximum velocity	= + 26·09 km.
Minimum ,,	= + 18·55 km.

—*Astrophysical Journal*, Vol. 30, pp. 26-32, July, 1909.

BOTANY.

By G. MASSEE.

TRANSPIRATION OF PLANTS.—This has long been a subject that has attracted attention, and recently in connection with the modern study of ecology is considered as a factor of primary importance. As a rule, however, the influence of physical factors on transpiration have not been taken into consideration. A. W. Sampson and L. M. Allen therefore attempted to measure transpiration with special reference to these conditions. The following are the most important conclusions arrived at :—

Variation in transpiration per unit area for a given time was found to be but slight, for plants of the same species, of about the same age, grown and tested under similar conditions, whether in their natural habitats, or in a conservatory.

Of polydemic forms, when measured in their natural habitats, those growing in the sun lose from two to four times as much water as those growing in shade. This inequality is mostly explained by the fact that the sun form has generally twenty to sixty per cent. more stomata per unit leaf surface than the form grown in shade. This function is also accelerated by the greater activity which takes place in the sun form.

An increase in altitude, other things being equal, results in increased transpiration. This, however, is not due to increased intensity of light and a lower air humidity, as is generally supposed, but is due to decreased pressure. This can be proved by the fact that in experiments under control, the greatest amount of transpiration takes place under the least amount of pressure.

The transpiration of *Scirpus lacustris*, a "bog xerophyte," is almost twice as great as that of *Helianthus annuus*, a typical mesophyte with characteristic palisade and sponge tissue. This is explained by the great amount of transpiring tissue present in *Scirpus*. The external surface protected by epidermis is fifteen times less than the inner transpiring tissue. Of the total volume of the stem, four-fifths is composed of air chambers.

Broadly speaking, acid solutions accelerate transpiration, and alkaline solutions retard it, as compared with plants in distilled water.—(*Minnesota Botanical Studies*, Part I., Vol. IV.)

EMBRYOLOGY OF SYMPLOCARPUS FŒTIDUS.—C. Otto Rosendahl gives an account in *Minnesota Botanical Studies*, Vol. IV., of the development of the embryo in the skunk cabbage, *Symplocarpus fœtidus*. The inflorescences develop very slowly, and the rudiments of the flowers are distinguishable from eighteen to twenty months before the time of blossoming. The ovules are developed during the late summer and autumn of the year before blossoming. In most cases the ovary is one-chambered, and contains one orthotropous ovule, pendant from the upper part of the ovary.

During its growth, the embryo completely consumes the endosperm, with the integuments of the ovule, consequently it eventually lies practically naked in the cavity of the ovary, and hence no real seeds are produced in *Symplocarpus fœtidus*.

SPERMATOZOIDS OF LYCOPODIUM.—Dr. H. Bruchman has described in *Flora* certain experiments made upon the spermatozoids of *Lycopodium*, and considers that they respond to the chemotactic action of free citric acid, or of solutions of its salts, and by such means are attracted to the archegonia. Citric acid is considered to play many parts in the biology of the prothallus in species of *Lycopodium*. The sap of the prothallus is weakly acid, and the presence of the acid is considered to be due to the saprophytic habit, and, perhaps, partly to the presence of an endophytic fungus. In addition to being the means of securing fertilisation, it appears to afford protection against insects.

ANTARCTIC MOSSES.— Professor Cardot has furnished a detailed account of the Antarctic moss flora, in the report of the Swedish South Polar Expedition. The numbers of determined species are: 137 for the Magellanic region; 80 for South Georgia; and 23 for the Antarctic region. Among these, four genera and 65 species are new. All previous work on the subject has been revised, and shows that out of 444 species recorded for the Magellanic region, 243 are endemic. In South Georgia 42 species are endemic out of 93, and in the Antarctic region proper, 24 are endemic out of a total of 47. It is shown with certainty that the moss-flora of the Magellanic region has greater affinity to that of Australasia than to that of Patagonia, the former land connection being indicated by Falkland Islands, South Georgia, Kerguelen, New Zealand, etc.

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THE FLORIDA VELVET BEAN.—Twenty years ago this plant was practically unknown; at the present day it is the most important forage crop grown in Florida, and, for ploughing under green, as a fertiliser it is also grown in hundreds of orange groves. It is also cultivated in other parts of the United States, Australia, India, etc. The original source of the species is unknown. The plant was first identified as *Dolichos multiflorus*, afterwards as *Mucuna pruriens*, var. *utilis*, finally it has been described as a new species, *Stizolobium deeringianum*, Bort., in *Bulletin* No. 141, U.S. Dept. Agriculture. The plant is a climbing annual, reaching a length of 20 yards or more when growing on a support, bearing long pendant racemes of purple flowers; pods dark coloured, velvety.

CHEMISTRY.

By C. AINSWORTH MITCHELL, B.A. (Oxon.), F.I.C.

THE DANGERS OF CARBON TETRACHLORIDE. —It is only within the last few years that carbon tetrachloride has become a general article of commerce, and at first it was almost exclusively used as a solvent for extracting fat from bones and other materials, for which purpose, being non-inflammable, it is admirably adapted. The factories that installed plant for the use of carbon tetrachloride in place of benzine or carbon bisulphide were thus able to carry on their business within the vicinity of dwelling houses, and to obtain special terms from the fire insurance companies. As this property of the new solvent became known various scented preparations were sold to the public for cleaning gloves and wearing apparel, and provided the cleaning is done in the open air, or in a good draught, there is absolutely no risk in using it for this purpose. It is quite another matter when the carbon tetrachloride is used for cleaning the hair.

With regard to the relative toxicity of carbon tetrachloride and chloroform, the results of physiological tests on the isolated nerve made by Dr. A. D. Waller are recorded in the current number of the *Lancet*. From these it appears that chloroform is about 100 times more poisonous than alcohol, and that pure carbon tetrachloride is about twice as toxic as chloroform. The particular preparation used in the fatal case was still more poisonous than pure carbon tetrachloride.

An analysis made by Dr. V. H. Veley showed that this preparation consisted of approximately 94 per cent. of carbon tetrachloride, 1.5 per cent. of carbon bisulphide, and 4.5 per cent. of water and scent. The presence of the carbon bisulphide, an impurity of the manufacture, probably accounted for the increased toxicity of the liquid, for carbon bisulphide has long been known to be extremely poisonous. The proportion is certainly too high, and samples of carbon tetrachloride examined by the present writer have contained much less. Pure carbon tetrachloride boils at 76.5° C., but the boiling point of commercial preparations is usually slightly lower owing to the presence of impurities. In Dr. Veley's opinion the danger is so urgent that a Bill should be passed prohibiting the use of carbon tetrachloride as a hair dressing, and also its employment in laundries except in a closed vessel.

ALLOTROPIC MODIFICATIONS OF PHOSPHORUS.—It has been shown by M. P. Jolibois that when red phosphorus is mixed with water and the liquid fractionally decanted, it can be separated into coarse particles of a deep violet colour and fine yellowish red particles. The change from one form into the other may be effected by simply crushing the larger particles. Hence the change of colour, which has hitherto been regarded as characteristic of a different allotropic modification, may be solely due to the fineness of the particles. On heating the large particles of red phosphorus in a sealed tube, in the absence of air, to 400° C., the colour changes from deep violet to red, and the specific gravity from 2.18 to 2.37, and the modification produced is not altered when the heating is continued at 600° C. The specific gravity of phosphorus does not, therefore, as is commonly accepted, depend upon the temperature.

Ordinary commercial red phosphorus, which is prepared by heating white phosphorus at a definite temperature, is regarded by M. Jolibois as being in an unstable condition, since heating it at its temperature of formation, in the presence of a trace of iodine, is sufficient to transform it into the stable, modification of specific gravity 2.37, for which the name of *pyromorphic phosphorus* is suggested. Incomplete transformation of the red phosphorus into the pyromorphic modification results in the formation of a puce-coloured product, which microscopical examination shows is in a state of "solid solution," since the particles of the two varieties are not lying in juxtaposition.

When red phosphorus is fused in sealed tubes at 725° C., it is converted into a violet modification with a specific gravity of 2.27. This remains unaltered when the tube is suddenly cooled.

GEOLOGY.

By EDWARD A. MARTIN, F.G.S.

THE CHALK OF TEXAS.—In the *American Journal of Science* there is an article on the chalk formations of Northeast Texas, by C. H. Gordon. The classification adopted for the Upper Cretaceous is as follows:—

Navarro and Taylor, consisting of dark laminated clays and blue sandy shales, glauconitic sands: an impure sandy chalk, 40 to 50 ft. thick.

Austin Formation, with bluish and creamy white chalk (50 to 100 ft.), known as the Annona Chalk, and blue marly clay (400 to 500 ft.), known as the Brownstown Marls.

Eagle Ford Formation, consisting of the Blossom Sands, glauconitic, grading into clay. They contain nodular septaria, which are often fossiliferous. 500 to 600 ft. thick.

Woodbine Formation, being ferruginous and argillaceous sands, in places glauconitic and lignitiferous, with an estimated thickness of 500 to 800 ft.

Mr. J. C. Taff, of the U.S. Geological Survey, refers to the Texas deposits and says: "The white chalk is exposed from Austin northward to Sherman, Texas, through a distance of nearly 250 miles, without appreciable change in its thickness of nearly 600 ft., and with very slight variation in texture, colour, and nature of material."

TRIASSIC REPTILIAN TRACKS.—Some Reptilian Tracks from the Trias of Runcorn (Cheshire), were described by D. M. S. Watson, B.Sc., at the last meeting of the Geological Society. Very little information exists as to the tracks of the smaller reptilia of the Trias, although several types of footprints have been described from isolated examples. Four types of tracks which occur on the slab of sandstone from Weston Point, described in 1840 by Dr. Black, were discussed in the paper. They belong to forms generally included in the Rhynchosauroid types. It is suggested that some of these prints may quite well belong to such Thecodonts as *Ornithosuchus*.

THE BURNING CLIFF AT LYME REGIS.—In the *Journal* of the Torquay Natural History Society there is an interesting paper by A. J. Jukes-Browne, on the "Burning Cliff and the Landslip at Lyme Regis," which took place last year, glowing accounts of which appeared in the papers at the time. The landslips took place along a track 500 yards in length, the largest fall occurring about a quarter of a mile N.E. of Lyme Regis.

The causes which specially conduced to these cliff falls were considered to be (1), the abstraction of limestone from the shore below; (2), the soakage of water into the cracks which form on the slopes.

Quarrying of limestone from the ledges, which crop out on the foreshore, has gone on for many years, and as these ledges are followed up to the foot of the cliffs, the removal of stone has weakened the cliff foundation, and has enabled the waves at high water to break with greater force against the cliffs. The so-called burning cliff was merely a pile of shale, iron pyrites, and cement stones, which had fallen from the second cliff on to the terrace below. This took place early in January, and the mound began to smoke about January 19, causing the report of a volcano at Lyme Regis to be circulated in the newspapers. What really

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occurred was the combustion of bituminous shale, owing to the heat developed by the rapid decomposition of the iron pyrites mixed with it. Such heating often takes place in similar formations.

THE GRAVELS OF TAPLOW.—On September 18 the Geologists' Association will visit Taplow and Burnham Beeches. On arrival at Taplow, a fine section of gravel belonging to a terrace of Thames Valley drift at 100 ft. O.D., will be visited; palæoliths and mammalian remains are to be found. Burnham Gore will be visited, where a gravel pit in the main implementiferous terrace will be seen. At Littleworth Common, a gravel-covered plateau, 310 ft. O.D., a good section will be seen containing abundance of large quartzite pebbles and other northern drift material. The secretary for the excursion is Mr. H. Kidner, F.G.S.

METEOROLOGY.

By WILLIAM MARRIOTT, F.R.MET.SOC.

LIGHTNING PHENOMENA.—The name of the writer of the note on this subject referred to in last month's "KNOWLEDGE" was Mr. Alexander Sinclair.

Sir Oliver Lodge has communicated to *Nature* the following remarks on the subject:—

"An observation sent me by Mr. Alexander Sinclair, of Swansea, to the effect that during a thunderstorm drops of water leaking through the ceiling 'assumed a pear-shape and jumped 9 inches almost horizontally to the curtain-rings above the window,' suggests that house-bells of the ordinary non-electric type may occasionally be rung by this means. I picture the process as follows:— The bell-wires collect atmospheric electricity, by induction or otherwise, which the walls are insufficiently conducting to carry off freely; consequently the bells get charged, are attracted to a neighbouring wall or pipe, and released suddenly by a spark. This little lateral jerk rings the bell. I put the simple suggestion on record, because I sometimes hear of an inclination to attribute the phenomenon to less familiar causes."

MEANING OF THE TERM EUROCLYDON.—In the U.S. *Monthly Weather Review*, Professor Cleveland Abbe states that the term "Euroclydon," which appears in *Acts*, Ch. xxvii., v. 14, as a Greek word, is simply a transliteration to suit Greek taste for euphony of the Phœnician or Hebrew words *eulos krudon*, a strong wind, which itself must have been closely allied to some Arabic term.

HEAVY RAINFALLS.—Dr. Ereida has published a paper dealing with the severe thunderstorms of November 17 and 18, 1908, in Sicily, which produced disastrous floods, especially in the provinces of Syracuse and Catania. The heaviest recorded rainfall was at Riposto, where 18.29 ins. fell on the 17th and 8.11 ins. on the 18th. The downpour was most intense from 15.50 to 16.15 on the 17th, when more than 150 mm. [5.90 ins.] of water fell in the 25 minutes.

This is one of the heaviest recorded rainfalls in so short a space of time, being at the rate of more than 14 inches per hour.

The following are some of the heaviest rainfalls recorded in other parts of the world:—

41 ins. at Suva, Fiji, on August 8, 1906.

40.8 ins. at Cherrapunji, Khasia Hills, India, on June 14, 1876; and in the same month five consecutive days produced 115 ins. of rain, or nearly 23 ins. per day.

At Tanabe, in Japan, 35.4 ins. fell in one day, and 50 ins. in 40 hours.

At Purneah, in North Bengal, 35 ins. fell in one day.

The greatest amount of rain in one day in Great Britain was 9½ ins. at Scarborough on August 6, 1857. The gauge, however, overflowed, so the rainfall might have been more than 9½ ins.

ATMOSPHERIC INFLUENCES CAUSING MOVEMENTS OF THE SOIL.—Professor Cleveland Abbe, in the U.S. *Monthly Weather Review*, points out that the records made by seismographs show that in general the superficial layer of gravel, clay, sand, or other form of loose soil, resulting from the disintegration of solid rock, is subject to a variety of movements that have no connection with earthquakes properly so-called.

Among these microseismic movements many have a meteorological origin; such are the slow tiltings due to the infiltration of rain water, the freezing of the ground, the pressure of the wind against the walls of the buildings, the changes of atmospheric pressure and resulting changes in the weight of the superincumbent atmosphere, the added weight of a mass of freshly fallen rain or snow, the melting of glaciers and the diminished load on the continent, the changes in level and consequently in weight and pressure of large interior lakes, the analogous changes in the level and pressure of the ocean water on the sea coasts due to winds and tides.

There are other movements due to strains in the solid rocky substratum or to the relief from strain; these belong to vulcanology and astronomy, and are traceable back to luni-solar tidal strains, to strains due to changes in the rotation of the globe, to volcanic heat and chemical changes, to the changes of aggregation that take place when amorphous strata slowly crystallise under pressure.

The slow tiltings, or long tides that are so evident in every seismogram, are frequently spoken of as due to the varying load of air, rain, or snow, acting on the solid rocky shell of our globe; but Professor Abbe is inclined to believe that these tiltings may be due to the influence of changes of load on our superficial soil, 5, 10, or 50 feet in depth, resting on a relatively rigid rocky soil. This soil is permeated with water and air. Like a sponge, it yields to every change of pressure. The water in deep wells, the water tables, the flow of underground water, are usually found to vary with barometric pressure as plainly as they do with rainfall or melting snow, or freezing temperatures. The explanation of any local tilting phenomenon will not be satisfactory until we have thoroughly studied the influence of atmospheric pressure on the soil and on the ground water below the seismograph.

The study by Professor Franklin H. King, of the Agricultural Experiment Station at Madison, Wis., on the behaviour of ground water shows how our seismographs are liable to be affected by changes of pressure and the reaction of the air below a wet soil.

ORNITHOLOGY.

By W. P. PYCRAFT, F.L.S., F.Z.S., M.B.O.U., &c.

A NEW LIGHT ON THE LIFE-HISTORY OF THE WATER-RAIL.—In *British Birds* for August Miss E. L. Turner gives a remarkable account of some observations on the ways of the Water-rail at the time when the eggs are hatching, and this is supplemented by some really wonderful photographs.

A female whose eggs were on the point of hatching was being kept under observation, for the purpose of securing photographs. It would seem that the story so vividly told had its origin in the removal of the empty shells, from which two young had emerged, by the keeper who was assisting Miss Turner. For no sooner did the bird discover this interference in her domestic arrangements than she seized one youngster by the neck and carried him off; then returning, she caught "the second unfortunate and bedraggled-looking chick by the head and whisked him off." She then returned for the third, not yet out of the shell, and seizing him by the shoulder removed him shell and all, and the fourth also in like manner. There remained only one addled egg, but though this formed a very difficult task, after several unsuccessful efforts she succeeded in getting a firm grasp of it and disappeared. . . . After this the bird returned twice to the nest, and thus apparently satisfied as to its emptiness we saw her no more."

Of course, many instances are on record of birds which have removed their eggs when under the influence of fear, but so far we do not believe the actual work of removal has ever been witnessed.

CROSSBILLS IN GREAT BRITAIN.—Considerable numbers of Crossbills seem to have made their way into Scotland during the end of June, and later to have worked southwards into England. Some interesting particulars thereof will be found in the August issue of *British Birds*. Dr. N. F. Ticehurst sends a short account from the Orkney Islands. On June 29 he noticed a single bird in a row of stunted sycamores, on the S.E. mainland, and on the following morning there were two others. These were immature birds, having striped breasts. They were seen again on July 1, and then seem to have passed on; the wind having changed from N.E. to S.E.

Mr. Meade-Waldo reported them from the Shetlands on July 2, but he remarks: "They had been seen for some days previously." The first seen were scattered individuals, but later, on Fell and Mainland, they were met with in small flocks, containing both old and young birds; and all seemed in great straits for food, many being in a starving condition. On reaching Hever, Kent, on the morning of July 15, a flock flew over him, and one flock of at least a hundred birds was seen later.

In Hampshire many were seen so early as July 4, and they were also seen near Godalming, Surrey, and Northwood, Middlesex, during July.

Mr. Henry Scherren, in the *Field* (August 14), remarks that Herr Weigold, of the Biological Station in Heligoland, announced them in that island during the same months. In his opinion the birds came from the north and northeast, after, be it noted, the birds had exhausted the food supply in the pine forests owing to an abnormal increase in numbers after a successful breeding season.

BRUNNICH'S GUILLEMOT IN YORKSHIRE.—Mr. Oxley Grabham, in *British Birds* for August, records the fact that on June 27 last he saw on the Bempton Cliffs an undoubted example of Brünnich's Guillemot (*Uria bruennichi*), in company with a Common Guillemot. As he had ample leisure for the study of this bird, there need be no doubt about his identification.

In his note he refers to the fact that the late Lord Lilford regarded the Brünnich as a geographical race of the Common Guillemot, and further remarks: "I have examined scores of Guillemots at different times, both in winter and summer plumage, and have found all gradations between the Brünnich's, the large Baltic race, and ours, running one into the other." This is a most interesting observation, and should be carefully noted by all who are interested in the problem of the origin of species.

GUILLEMOTS AND RAZOR-BILLS AT SEA.—As everybody knows, as soon as the young of the Guillemots, Razor-bills, and Puffins are fully fledged they are taken by their parents down to the sea, whereby the cliffs, till then the scenes of amazing and restless activity, become converted into frowning precipices, guarded, perchance, by hosts of shags and cormorants, who, like grim sentinels, keep watch and ward till spring returns. But what happens to the hosts of old and young of these tenants of the upper ledges?

I have just returned from a short visit to the North of Ireland, making my way thence from Heysham to Derry by sea. On the way out and home, I met with large numbers of Guillemots and Razor-bills and a few Puffins far out at sea—8 or 10 miles from land. These were encountered in scattered individuals, or small parties of 8 or 10; often quite young birds were seen piping to the parent for food. Off the coast of Donegal, at Horn-Head, and the region thereabouts, the same facts were noted. Only a very few were seen in shore, and none on the rocks. One or two Black Guillemots, it may be noted, were seen here. It would seem that the winter is passed thus at sea. Why is this? So far we seem to have no very detailed account of this phase in the life-history of these birds, and this is a fact much to be regretted. What do these birds find to feed on during this time? What are the causes which keep them afloat throughout so long a period? Do they return at night to roost? It is quite possible that some of my readers may be able to enlighten me on these points; but there seem to be no printed records of the kind.

PHYSICS.

By PROFESSOR A. W. PORTER, B.Sc.

THE BEHAVIOUR OF IRON AND STEEL UNDER CYCLICAL VARIATIONS OF STRESS.—It is found by L. Bairstow that iron or steel is capable of adjusting itself to variations of stress, cyclically applied, after a sufficient number of repetitions. When the adjustment is complete the specimen under test is found to have become perfectly elastic throughout the whole cycle, and fatigue does not occur. During the adjustment of the elastic limits, a change of length occurs in the specimen, which corresponds to the extension observed in an ordinary tensile test when the yield stress is exceeded. For stress cyclically applied, this extension occurs even when the maximum stress in the cycle is less than the static yield stress.

Limits can be found to this power of adjustment and, if the cycle of stress imposed exceeds these limits, the specimen becomes or remains unelastic and work is absorbed during each cycle. The work is extended in moving portions of the crystals of the material relatively to one another and is probably associated with microscopic slip-lines which gradually develop into cracks and ultimately cause the fracture of the specimen.

STANDARDISATION OF RADIUM.—Dr. Geiger, working in Professor Rutherford's laboratory, suggests the following result as affording a means of measuring small quantities of radium. The total ionisation current due to a gramme of radium at its minimum activity and spread out in an infinitely thin film on a plate so that one-half of all alpha-particles are absorbed in ionising is 1.21×10^6 electrostatic units. In applying this result it must be remembered that the figures given refer to complete saturation. Or the ionisation currents at a low pressure in a conducting bulb may be measured. The number of ions produced by a single alpha-particle under particular conditions is easily found from a curve given in his paper; the experimental determination of the ionisation current under similar conditions then gives at once the number of alpha-particles. Care has to be taken to obtain saturation and to avoid the ionisation by collision, which occurs when too large a voltage is applied.

ZOOLOGY.

By R. LYDEKKER.

A BRITISH MARSUPIAL.—Years ago a great controversy took place between two English naturalists—Falconer and Owen—as to the affinities of a tiny extinct mammal known at that time merely by a few more or less imperfect specimens of the lower jaw, obtained from the so-called dirt-bed of the Purbeck beds near Swanage. These jaws, as shown in Fig. 1, are characterised by the presence, on each side, of a relatively large spear-like incisor, followed, after an interval, by three tall compressed teeth, whose cutting crowns are marked by conspicious oblique grooves. From these oblique grooves Falconer gave to the animal to which the jaws belonged the name *Plagiaulax* (πλάγιος, oblique, and ἄυλαξ, a groove). It will be observed that the last of these three groved teeth is considerably larger than either of those in front of it, and that it is followed by a couple of lower and smaller teeth, which show a median groove flanked on each side by a row of cusps. It was suggested at the time that the three obliquely-grooved teeth were premolars, while those behind them were true molars; and subsequent discoveries have confirmed this interpretation.

Struck by the general resemblance of its dentition to that of the Australian kangaroo-rats, or rat-kangaroos, then known as *Hypsiprymnus* (a name now replaced, unfortunately, by *Potorous*), Falconer came to the conclusion that *Plagiaulax* was a herbivorous marsupial more or less nearly akin to the living genus. This, however, was disputed by Owen, who pointed out that, when the jaw was horizontal

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the condyle, or knob by which it is articulated to the skull, lay below the plane of the lateral, or cheek-teeth. And since such a character is found in modern carnivora, he argued that *Plagiaulax* must likewise have been carnivorous. Other naturalists, however, among them Sir William Flower, sided with Falconer.

Thus matters stood till 1881 when a last lower premolar tooth of the same general type as that of *Plagiaulax*, but

Fig. 1.—Right Half of Lower Jaw of Plagiaulax becklesii. Inner view. About natural size.

Fig. 2.—Right Half of Lower Jaw of Ptilodus gracilis. Inner view. ¾ natural size.

relatively larger, was discovered in the Lower Tertiary strata of North America and named *Ptilodus*. Subsequently more or less nearly complete lower jaws of the genus were obtained (Fig. 2), some of which showed that the full dentition included four pairs of premolars and two of molars.

From the evidence of the new genus the great American naturalist Cope came to the conclusion that Falconer was right in referring the Dorsetshire mammal to the marsupials, and likewise in regarding it as a relative of the kangaroo-rats. Subsequently, when the existence of temporary teeth in the duck-billed platypus of Australia was discovered, it was suggested that *Plagiaulax* and *Ptilodus*, together with a number of related extinct genera, were really members of the egg-laying, or monotreme group; and this view has been very generally entertained till a few weeks ago.

In June of the present year, Mr. J. W. Gidley, of the U.S. National Museum, from whose paper the accompanying figures are copied, was enabled to announce the discovery of a nearly complete skeleton of *Ptilodus* in the Lower Tertiary strata of Montana, and at the same time to definitely declare that both this genus and the English *Plagiaulax* are marsupials belonging to the same group as the modern Australian kangaroo-rats. Nor is this all, for the new specimen made it perfectly clear that certain molars from the English Purbeck upon which the supposed genus *Bolodon* had been founded, were really the foremost cheek-teeth of *Plagiaulax*, while somewhat similar American teeth, described as *Chirox*, were proved to belong to *Ptilodus*.

Thus ends a great controversy, with a complete confirmation of Falconer's original opinion. It is, however, interesting to note that Owen was right in his contention that an animal in which the condyle of the lower jaw was situated, when the jaws were in action, below the plane of the cheek-teeth, could not be carnivorous. For the new American specimen shows that the lower jaws of both *Plagiaulax* and *Ptilodus* were hung obliquely to the long axis of the skull, as in our figures, thereby enabling the large last lower premolar to bite against upper teeth of a lower and simpler type, and at the same time raising the condyle above the plane of the cheek-teeth after the fashion which Owen pointed out to be characteristic of herbivorous mammals.

The account of this very interesting case having reached the average length of these notes, further contributions to this column must be deferred till next month.

REVIEWS OF BOOKS.

ASTRONOMY.

Annals of the Astronomical Observatory of Harvard College.—The various funds at Professor Pickering's disposal for printing purposes have allowed the publication of several volumes or instalments within the last few months. Vol. LIV. contains a catalogue of 36,682 stars fainter than the magnitude 6.50, observed with the 4-inch meridian photometer, forming a supplement to the revised Harvard Photometry. Vol. LVII., Part II., gives comparison stars for 252 variables of long period, prepared for publication by Leon Campbell. Vol. LVI., No. IV., classification of 1,477 stars by means of their photographic spectra, by Annie J. Cannon. Vol. LXIV., Nos. I., II., and III. contain respectively observations with the meridian photometer during the years 1902 to 1906; the variable star S.S. Cygni, 213,843, by Leon Campbell; and Schönfeld's comparison stars for variables, with the exception of Miss Cannon's spectroscopic contribution, all the above are connected with the Harvard speciality of photometry. Vol. LX., however, is to contain a wide selection of subjects: I. Geometrical methods in the theory of combining observations; II., Early observations of the sixth satellite of Jupiter; III., Positions of Phœbe, 1898-1904; IV., 1,777 variables in the Magellanic clouds; V., Ten variable stars of the Algol type; VI., Nebulæ discovered at the Harvard College Observatory; VII., Double stars south of -30°, and of magnitude 6.3 to 7.0; VIII., a catalogue of bright stars and nebulæ; IX., a catalogue of photographic charts of the sky.

A Treatise on Spherical Astronomy, by Sir Robert Ball (Cambridge: University Press, 1908; pp. xii. and 506; 12s. net).—Some months ago, at a meeting of the Royal Astronomical Society, Sir Robert Ball contributed a paper "On a Single Equation which Comprises the Theory of the Fundamental Instruments of the Observatory." Any speculations as to the circumstances that produced this paper are now set at rest, for it falls into its appointed place in the Lowndean Professor's latest contribution to student astronomy. The work of Newcomb is so recent that one might be inclined to wonder at the issue of another book with the same title in the same language so soon afterwards, but in the first place it is obvious that this book has been the work of a considerable space of time, and has only lost priority by accident, so to speak, and in the second place, it is equally obvious that the books are not at all alike. The author, while theoretically confining his attention to "that part of mathematical astronomy which lies between the vast domain of dynamical astronomy on the one hand, and the multitudinous details of practical astronomy on the other," has found it necessary for the due rounding off of his subject to cross the border lines occasionally, giving, for instance, a little dynamical astronomy in connection with the chapter on the laws of Newton and Kepler, and two whole chapters on the fundamental instruments. The book is very well adapted for the needs of the student reading for the Mathematical Tripos. It is not so many years ago that tutors were nearly at their wits' end to find a book to recommend for that purpose, and though at least three American books can now be confidently used, it appears that for practical educational purposes, the present work will be found extremely valuable if only for the splendid selection of examples from Tripos and College Examinations and other sources. It seems a little unusual to find these sources carefully indexed; conscientousness could not go much further, outside a concordance. The author finds an appropriate meaning for "nole," which he uses to represent the left-hand pole of a graduated great circle; to a traveller outside the sphere in the direction of increasing angle (clockwise, so to speak), "antinole" being, of course, the other pole. The old word, often spelt "noll," did not mean the same thing, but, being obsolete, 'twill serve; and the spelling is sufficiently like that of "pole," as the author remarks, to give a sort of clue to its intended meaning. Even with the limitations laid down, the range of the subject is so extensive, from map-making, refraction, aberration, parallax and star corrections, to the calculation of eclipses and occultations and the determination of orbits from observation, and from Kepler's laws to practical navigation and the setting of a sundial, that detailed criticism is out of the question here. The general impression is that of a thoroughly useful text-book, worthy of the distinguished position of its author in the astronomical world.

BOTANY.

The Book of Nature Study, Vol. IV.; by J. Bretland Farmer, M.A., D.Sc., F.R.S. (The Caxton Publishing Co.).—So far as the section dealing with flowering plants is concerned we can only repeat what was stated some

short time ago in noticing the first volume dealing with plants. It is excellent; the information is exactly what a first course of elementary botany, taught in a class-room, should be. Whether it is "nature-study," is a personal factor. One redeeming feature is the fact that the information so lucidly given is just what is required before entering on Nature study proper. The section dealing with the lower forms of plant life does not come up to the standard of previous sections. The fungi, numerically the largest group following flowering plants, is dealt with in, to say the least, a very slipshod manner, notwithstanding the fact that fungi, from an economic and ecological standpoint respectively, cannot afford to be ignored in any work essaying to demonstrate the interaction between different sections of the vegetable kingdom. Judging from the amazing statement that "hardly a single plant-disease is due to bacteria," we presume that Rip Van Winkle was responsible for the chapter on bacteria. We beg to refer the writer to Dr. E. F. Smith's "Bacteria in Relation to Plant Diseases," published in 1905. The illustrations are numerous and excellent, and the entire work is one that cannot be dispensed with by anyone desirous of becoming acquainted with the general structure and mode of life of the various groups constituting the plant world.

Trees and Flowers of England and Wales, by H. G. Jameson, M.A. (Simpkin, Marshall, Hamilton, Kent, and Co., Ltd.; 2s. 6d. net).—The author commenced this book with one specific object in view, that of enabling the reader to determine with accuracy the name of any British flower or tree. This object has been carried out with consistency and remarkable accuracy. The key system is adopted, and its use explained under four headings—(1) Plan of the book. (2) Collection and examination of plants. (3) Explanation of the terms used—illustrated. (4) How to use the Key. Each species of plant has a small, marginal figure illustrating the essential specific features, and although these figures are small, they are remarkably clear and accurate. The whole subject has been so thoroughly worked out that, while of service to the beginner, it will also prove a boon to the expert for use in the field.

The Cryptogamic Flora of Leicestershire, by A. R. Horwood (Leicester: Thornley and Waddington).—This is an excellent piece of work, dealing with those members of the Vegetable Kingdom usually ignored in so-called County Floras. The species in most instances have been critically determined, and habitats of previous records verified. As stated by the author, it is obvious that the numbers of some of the groups enumerated will be considerably extended in the future; nevertheless, the present contribution will serve as an excellent starting-point.

GEOGRAPHY.

Geographical Discovery, by Joseph Jacobs (Hodder and Stoughton; 24 maps; 1s. net).—This little volume is an excellent epitome of the subject, and contains a good deal of out-of-the-way information. From internal evidence it appears to have been published first in 1898, although the title-page bears date of 1909. It is therefore not quite up to date.

GEOLOGY.

Practical Exercises in Geology, by B. C. Wallis, B.Sc.; 183 pp.; 2s. 6d.; also **A Geography of the British Isles,** by A. Morley Davies, D.Sc.; 358 pp.; 3s.—These two works, published in Macmillan's "Practical Modern Geographies" Series, are deserving of the notice of all engaged in teaching up to date geography. A mere glance would show that they are very far from the ordinary text-book of a few years ago. The practical exercises deal with measurement of areas in the open-air, contour maps in sand, the thermometer and barometer, rainfall gauging, vegetation, rocks and minerals, and detailed descriptions of selected areas at home and abroad. In dealing with the British Isles Mr. Morley Davies has given us a more striking text-book than any we have so far met with on the subject. With but little new to say, the value of the book lies in the way in which it is said. We do not see here the mere schoolmaster giving a lesson, but a master of his subject speaking almost with affection for the facts which he handles. Such geography will carry the dullest schoolboy or student far more forward in his subject than in the older days when text-books were less attractive. We may add that both books are well supplied with illustrations, many being from excellent photographs.

MISCELLANEOUS.

The Manufacture of Paper, by R. W. Sindall (London: Constable and Co.; pp. x. and 275; 6s. net).—The rapid growth of the use of cheap substitutes for cotton and linen rags in the manufacture of paper has not proved an unmixed blessing. Apart from the inferiority of the fibres themselves, the chemical processes used in the preparation of such materials as esparto grass and wood pulp for the purpose, all have a weakening influence and tend to render the resulting paper containing them liable to be more rapidly affected by atmospheric conditions. Although it is still possible to obtain good paper, it is to be feared that much of that used for books at the present time will prove anything but lasting. For this state of things it is not fair to blame the manufacturer, for it is only another instance of quality being sacrificed to the demand for cheapness. In Mr. Sindall's book even the reader with no technical knowledge will gain an insight into the causes of this deterioration of paper. After an interesting historical introduction the nature of the raw materials, and the various mechanical processes and latest types of machinery used in the manufacture of paper are described in a thoroughly readable manner. The book is well illustrated and concludes with an excellent classified bibliography. We can thoroughly recommend it to everyone interested in the chemistry, or the use, of paper.

Modern Navigation, by W. Hall, R.N. (University Tutorial Press, price 7s. 6d.).—This is a text-book adapted to the cadet course of the Royal Navy, and the syllabus of the Board of Education. It is a second edition, but in writing it the old edition has been recast *in toto* in order to suit modern requirements. Obsolete portions, such as the lunar problem, have been omitted and all the model examples have been reworked in accordance with the newer and shorter methods made possible by the publication of the new edition of Inman's tables. Although the work only professes to deal with a subject of limited scope, it must be understood that the author has not taken this aim as an incentive to scantiness of treatment. For example, the introduction to spherical trigonometry includes more than is absolutely necessary for the purpose in hand. This thoroughness is characteristic of the book, and it may be recommended as a very able text-book.

The Theory of the Construction of Tables of Mortality. Lectures by G. F. Hardy (London: Charles and Edwin Layton, 56, Farringdon Street, 1909; 7s. 6d. net).—This consists of a course of lectures delivered at the Institute of Actuaries in 1904-5. They are of a thoroughly professional type, and to the ordinary reader they may seem very unattractive in spite of the fact that they deal with statistical questions relating to mortality, sickness, secession, marriage, superannuation, etc., which are questions of universal interest. Taken in conjunction with Mr. Elderton's "Frequency Curves and Correlation," also published by the same Institute, we may now claim to possess a complete compendium of the subject. Mr. Hardy occupies a leading position both as a mathematician and an actuary (he is now president of the Institute). This book may therefore be confidently recommended to those whom it may concern.

The Cambridge Natural History.—Messrs. Macmillan draw our attention to a material concession which they are making in the price of the ten volumes forming this important work. They offer to supply complete sets for £5 5s. each, against the regular price of £8 10s., the volumes being published at 17s. net each. We would remind our readers that the Cambridge Natural History is not only the standard work upon the subject to-day, but is likely to remain so for a considerable time to come. The offer, which is only available till September 30, provides an unique opportunity to acquire this valuable set of volumes.

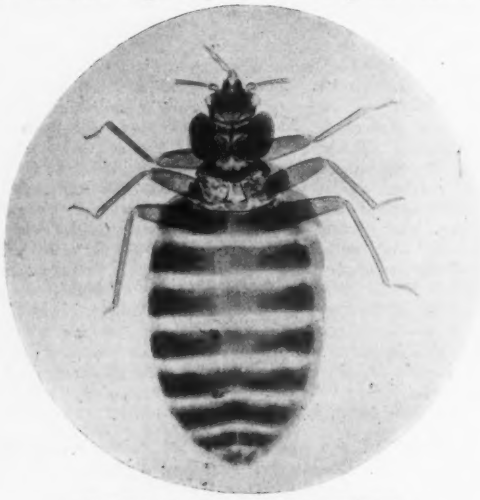
XUM

MICROSCOPY

Conducted by F. SHILLINGTON SCALES, M.A., F.R.M.S.

Low-Power Photo-Micrography.

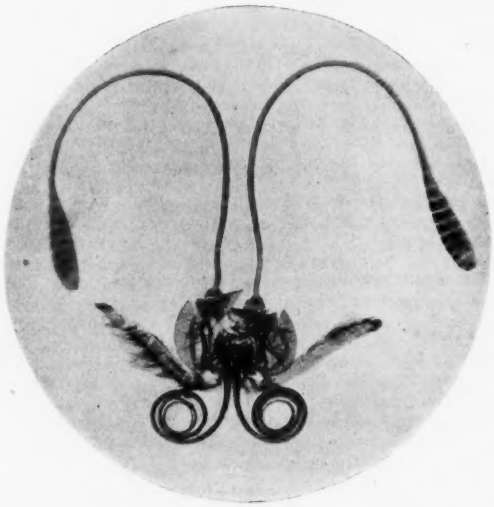
THE photography of microscopic objects with low powers is done under conditions which differ sensibly from those of medium and high power work. The important distinction lies in the fact that with low magnifications a comparatively large object is to be photographed and that there is difficulty first in getting the objective to take in the whole of the object, secondly, in getting the outer portions of the field in focus at the same time as the central portions, due either to roundness of field or to ill-corrected peripheral zones, and, thirdly, in illuminating evenly the whole of this extended field. Let it be said at once that for the very lowest magnifications of two to, say, three or even five diameters a good portrait lens gives results that



Bed Bug—Female (Acanthia lectularia).

are generally quite satisfactory and a microscope as such is not required. But beyond these magnifications a microscope objective is called for and special lenses of low magnification, very flat field and large covering power are made for the purpose by leading firms such as Leitz, Watson, and Zeiss. They vary in price from £4 to £6. Zeiss's lenses are well-known under the name of "Planar." But many of these lenses are too large to be used with the ordinary microscope-tube, and the tube needs therefore either to have a special fitting or to be made specially wide, or both. In most cases, however, it is sufficient to fit such lenses into a special carrier in the ring at the front of the camera whilst the slide is supported at right angles to the lens on a miniature easel, which may be of quite unpretentious home manufacture. The focussing is done by moving either the support for the slide or the ground-glass screen of the camera, the former method being that generally adopted and being the more convenient. The essential point about the illumination is that it must cover the whole field adequately, and for this reason the ordinary condenser, even with the top lens removed, gives too circumscribed a field of illumination and should be removed if the microscope is being used. The use of a disc of ground-glass gives a uniform and pleasantly illuminated field, but is apt to prolong the exposure, and the usual method is to make use of a large and well-corrected bull's-eye, adjusted with its plane side towards and near the illuminant, and so placed as to throw a full beam of light into the objective instead of on to the object. In fact, by adjusting the ordinary sub-stage condenser (with top lens removed) so as to focus in the plane of the objective rather than in the plane of the object and carefully centring it, it will often be found possible to get a satisfactorily illuminated field unless the objective be of very low power.

I have not succeeded in getting really good photographic results with ordinary low-power objectives such as a 2-inch or 3-inch; the field is circumscribed and the marginal definition poor, a fatal defect where one has probably had difficulty in getting the whole of the object into the field. Incidentally, it may be mentioned that few low-power objectives are true to their designations; a 3-inch turning out under measurement to be nearer 2-inch; a 2-inch nearer 1½-inch, and so on.



Head, Tongue, and Antennæ of Butterfly (Vanessa urticæ).

Some years ago I obtained from Reichert a low-power lens for photo-micrography which has been of the utmost service to me. It is 2¾ inches in focus, and contains a graduated diaphragm between the lenses, and is small enough to carry the Society screw, and so to fit into any microscope. Its definition is excellent, and the image is sharp up to the very edge of the field, whilst the price was quite moderate. The accompanying photo-micrographs, taken with this lens (though suffering considerably in reproduction), will show what ought to be expected in a good low-power photo-micrograph, and it will be observed that there is no loss of definition up to the very edge of the photograph, though this edge represents the actual edge of the field, the photographs not having been in any way cut down or trimmed. Similar results can be expected from the same type of lens made by other makers.

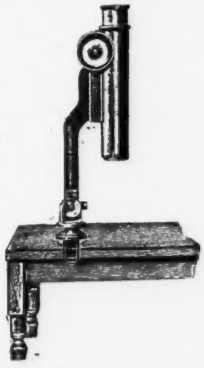
Hairs on the Proboscis of the Blow-fly.

The hairs upon the proboscis of the blow-fly have always been a favourite test with microscopists for

medium and moderately high-powered lenses, but Mr. E. M. Nelson has recently pointed out that they are not only a test, but also afford excellent practice in minute microscopical work, which may, with advantage, be undertaken before attempting the more difficult examination of the flagella of bacteria. Mr. Nelson calls attention (J.Q.M.C., 1908, pp. 122-3) to four kinds of hairs on the proboscis—minute curved spinous hairs on the upper surface of the very delicate membrane of the sucker which protect it whilst the insect is feeding, without impairing its flexibility either when expanded and in use or when flaccid and withdrawn, and whose curvature tend to more efficient protection; equally minute hairs upon the rostrum which are soft and pliable instead of being spinous; other hairs of much greater size found both upon the rostrum and upon the maxillary palpi, which are ribbed longitudinally, and a few of which have filamentous endings; and yet another kind of large hairs ranged round the edge of the suctorial disc which are tubular, with a flat flange on either side. These last work on the same principle as the tongue itself, as described by Mr. Lowne: "The proboscis is an erectile organ. It is flaccid and folded on itself when not in use, but is capable of being rendered rigid by the injection of air into the extensive tracheal sacs which lie in its cavities. When the proboscis is in use it is projected from the head capsule, and rendered stiff by the injection of air into its trachea. Its varied movements are brought about by the action of muscles; the flaccid proboscis is also folded and withdrawn into the head capsule by means of retractor muscles." The tubular hairs are erected by the same supply of air which inflates the proboscis. This renders them stiff enough to protect the delicate edge of the suctorial disc, yet when the tongue is relaxed they become flaccid and so in no way interfere with the folding up of the organ into the head capsule.

Naturalists' Microscope.

The microscope has become an instrument of the utmost precision, and of no little elaboration, but there is still much work which can be done with an instrument of the simplest construction and proportionate economy in cost. Messrs. W. Watson and Sons have just brought out a new microscope of this description, (illustrated in the accompanying figure) of simple



yet sound construction, with joint for inclination, coarse adjustment by rack and pinion, removable stage and mirror (which are not shown), but which instead of a stand fits into a socket that can be let into a table, a bench, or the side of the box containing the microscope. Such a microscope is quite suitable for what is now known as "Nature study," or for many country pursuits such as farming or dairy-keeping, or for gardening. The price of the microscope with socket is only 20s., with case 7s. 6d. extra, and with eye-piece and combination 2-inch and 1-inch objective, £2 3s. 6d.

Notes and Queries.

Orientating of Opaque Objects.—Mr. George S. Saunders, of Wandsworth Common, writes: "I have no doubt many others have also found a difficulty in arranging opaque objects in exactly the position and angle in which it may be desired to examine them under the microscope. I have lately adopted a very simple method, which admirably meets this difficulty. I take a small piece of plasticine (a substance used by children in modelling), press it on an ordinary glass slide, and slightly imbed the object in it in the desired position, which, if found to be not quite right can easily be altered without removing the slide from the stage. An insect on a pin can conveniently be examined in this manner, as the plasticine will hold the pin at any angle. Incidentally, this substance is useful for arranging a flower in a vase at the exact angle at which it may be wished to draw it, and in many other ways it is convenient, as it does not adhere unduly to the object, but comes away quite clean."

W. K. B. (Tientsin).—It is not easy to get good dark-ground effects with objectives having higher apertures than about 0.6 N.A. unless the condenser is one of the specially constructed paraboloidal type such as are now being made for use with $\frac{1}{2}$-inch and $\frac{1}{12}$-inch objectives. You would gain nothing by using an ordinary immersion condenser, as it is not increased aperture that is wanted, but a different construction. It is possible that by careful adjustment of the size of stop to the aperture of the objective referred to (0.65 N.A.) you might in this case get fairly satisfactory results, and this could be done either by means of a Traviss adjustable stop, which can be obtained to vary from $\frac{4}{16}$ to $\frac{3}{4}$ or even $\frac{9}{16}$ of an inch, or by cutting down the aperture of the objective by means of a diaphragm placed above it (*i.e.*, a Davis shutter), or by means of both. The aperture is, however, so great for this means of illumination that the results would in any case be inferior to those obtained by means of a paraboloid. The new immersion paraboloidal condensers recently introduced give good results with objectives over 0.6 N.A. as mentioned above, but they require very careful centring and adjustment, a powerful illuminant, preferably reinforced by means of a well-corrected bull's-eye, and slides and cover-glasses of definite thickness. In the case of immersion objectives the aperture of these must be cut down by means of a diaphragm so as not to exceed 0.95 N.A.

S. P. R. (Penarth).—I do not think you can do better than to obtain your $\frac{1}{12}$-inch immersion objective from the makers of your microscope. You will not easily get a better one. For ordinary medical work, such as is usually done by a medical practitioner, I think a lens of 1.2 N.A. will be quite satisfactory, but if you want to get good results with immersion lenses it is important to have a good condenser and to know how to use it, *i.e.*, how to centre and focus the illumination. I cannot advise you to get a second-hand lens unless you are quite sure that it is of recent manufacture and in faultless condition optically, but I think you could safely leave yourself in the hands of firms such as Chas. Baker. Personally, I should prefer to buy a new lens unless a very good second-hand one (really "as good as new") were offered to me.

New Catalogue.—Messrs. H. F. Angus and Co., of 83, Wigmore Street, W., have sent me an excellently arranged catalogue of microscopical accessories which ought to be of service especially to those who have to order such matters by post, in a hurry, and without undue correspondence, as very full tabulated details are given of the various kinds of apparatus. It contains lists and illustrations of collecting and dissecting apparatus, simple magnifiers, microtomes, mounting sundries, bacteriological, hæmatological, and medical analytical apparatus, lists of mounted slides for teaching, and a complete list of stains by Grübler and of other re-agents.

[Communications and inquries on Microscopical matters should be addressed to F. Shillington Scales, "Redcourt," Adams Road, Cambridge. Correspondents are requested not to send specimens to be named.]

XUM

The Face of the Sky for September.

By W. SHACKLETON, F.R.A.S.

THE SUN.—On the 1st the Sun rises at 5.13 and sets at 6.47; on the 30th he rises at 5.59 and sets at 5.40. The Sun enters the sign of Libra on the 23rd at 5 p.m., when autumn commences. The equation of time is negligible on the 1st and 2nd, hence these dates are convenient for the adjustment of sun-dials as only the longitude correction is needed. The positions of the Sun's axis, centre of the disc, and heliographic longitude of the centre are given in the following table:—

Date.	Axis inclined from N. point.	Centre N. of Sun's Axis.	Heliographic Longitude of Centre of Disc.
Sept. 3 ..	21° 41′E	7° 14′	214° 26′
,, 13 ..	23° 50′E	7° 13′	82° 23′
,, 23 ..	25° 22′E	6° 59′	310° 23′
Oct. 3 ..	26° 15′E	6° 34′	178° 26′

THE MOON:—

Date.	Phases.	H. M.
Sept. 6..	☾ Last Quarter	7 44 p.m.
,, 14..	● New Moon	3 9 p.m.
,, 22..	☽ First Quarter	6 31 p.m.
,, 29..	○ Full Moon	1 5 p.m.

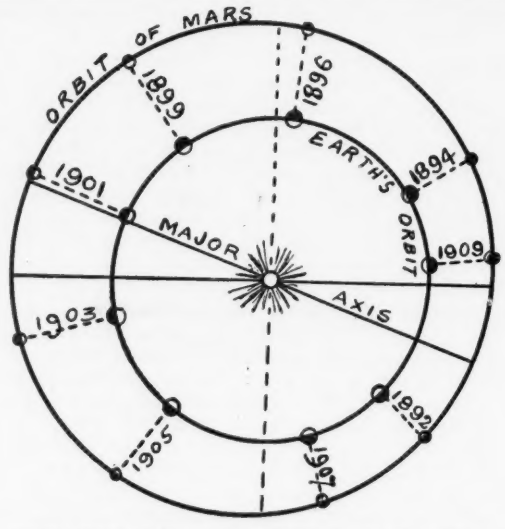
OCCULTATIONS.—The following are the particulars of the occultations visible from Greenwich:—

Date.	Star's Name.	Magnitude.	Disappearance.		Reappearance	
			Mean Time.	Angle from N. point.	Mean Time.	Angle from N. point.
			P.M.		P.M.	
Sept. 3	ξ′ Ceti.. ..	4·5	9.2	91°	9 50	216°
					A.M.	
,, 5	ω′ Tauri ..	5·8	11.51	355°	12.9	319°
					P.M.	
,, 23	σ Sagittarii ..	2·1	3.39	83°	4.53	286°
					A.M.	
,, 28	30 Piscium ..	4·7	11.7	79°	12.9	213°

THE PLANETS.—Mercury (Sept. 1, R.A. $12^h\ 2^m$; Dec. S. 0° 43′. Sept. 30, R.A. $13^h\ 37^m$; Dec. S. 14° 2′) is at greatest Easterly elongation on the 17th, hence about this date the planet is an evening star, setting at 6.44 p.m. on the 15th. The elongation is not a favourable one.

Venus (Sept. 1, R.A. $12^h\ 43^m$; Dec. S. 4° 4′. Sept. 30, R.A. $14^h\ 53^m$; Dec. S. 17° 43′) is an evening star in Virgo, setting at 7.15 p.m. on the 15th. In consequence of the low altitude, the planet is not well placed for observation as she sets about one hour after the Sun.

Mars (Sept. 1, R.A. $0^h\ 31^m$; Dec. S. 2° 38′. Sept. 30, R.A. $0^h\ 4^m$; Dec. S. 4° 33′) rises on the 1st at 7.58 p.m. and on the 30th at 5.50 p.m. On account of the planet's brightness and ruddy colour he forms the most conspicuous object in the evening sky, looking East soon after it is dark. The planet is in opposition to the Sun on the 24th, and thus about this date he appears on the meridian at midnight. This opposition is extremely favourable, since the planet attains a good altitude and also, being near perihelion, approaches unusually near the earth. The distance of the planet is about $36\frac{1}{4}$ million miles as compared with 35 millions at the most favourable and 61 million miles at the most unfavourable opposition. The diagram given shows the orbit of Mars relative to that of the Earth, with the oppositions from 1892 to 1902.



Relative Orbits of Mars and the Earth showing Oppositions from 1892 to 1909.

This opposition is more favourable than the last one in 1907, in that the relative distances are 0·390 to 0·408 and the luminosities 86 to 75; further, the planet is better placed for observation, since the meridian altitude is about 35° as compared with only 11° in 1907. The latitude of the centre is − 20°·4, hence the southern hemisphere is inclined towards the earth and is in the best position for observation. The snow cap appears very small, since the summer solstice of the Martian southern hemisphere occurs on Sept. 14, but, on the other hand, the dark markings will, according to Lowell, be correspondingly increased in intensity. The apparent diameter of the planet is 24″, and some of the principal markings should be discernible in telescopes of moderate aperture. The time of rotation is $24^h\ 38^m$, approximating to that of the earth, thus the same regions may be scrutinised on successive evenings. About the 19th the region of Syrtis Major is visible in the evenings. The planet is in conjunction with the Moon on 28th.

Jupiter (Sept. 1, R.A. $11^h\ 30^m$; Dec. N. 4° 26′. Sept. 30, R.A. $11^h\ 53^m$; Dec. N. 1° 58′) is in conjunction with the Sun on the 18th and consequently is unobservable.

Saturn (Sept. 1, R.A. $1^h\ 28^m$; Dec. N. 6° 18′ Sept. 30, R.A. $1^h\ 21^m$; Dec. N. 5° 33′) is a conspicuous object in the evening sky looking E, and is situated about one hour East of Mars. The planet is well placed for observation, and rises at 7.14 p.m. on the 15th. As seen in the telescope the ring appears open, being inclined to our line of vision at an angle of 13°, the Southern surface being visible. In a 3-inch telescope the ring should be visible with a power of about 50 and the belts on the planet's surface with a power of about 80.

Uranus (Sept. 15, R.A. $19^h\ 15^m$; Dec. S. 22° 49′), though rather low down in the sky, is fairly well placed for observation being due South shortly after dusk. The planet is situated in a part of the sky devoid of good reference stars, though the star ξ^2 Sagittarii is some 2° to the N.W.

Neptune (Sept. 15, R.A. $7^h\ 22^m$; Dec. N. 21° 25′) rises about 11.30 p.m. near the middle of the month, and is situated about half a degree South-East of the star δ Geminorum.

Mira (ο Ceti) is due at maximum about the 7th, and observations of its remarkable spectrum together with the variations in brightness should be made.